MODELING CUSTOMER-FOCUSED ENGINEERING PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

By

DAVID HERBERT HARTMANN

Bachelor of Science
United States Air Force Academy
Colorado Springs, Colorado
1969

Master of Science
Air Force Institute of Technology
Wright-Patterson Air Force Base, Ohio
1976

Master of Business Administration
The College of William and Mary in Virginia
Williamsburg, Virginia
1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
May, 2004

MODELING CUSTOMER-FOCUSED ENGINEERING

PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS

AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

Thesis Approved:

Kenneth E Case

Thesis Adviser

David B Pratt

Ramesh Sharda

Alfred Carlozzi

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to acknowledge the contributions, influence, guidance and, yes, thoughts and prayers of so very many family, friends, scholars, and colleagues during the process of completing this dissertation research. A "team effort", this research project developed the process to judge the priorities of four characteristics of graduate-level industrial engineers presenting themselves for professional employment: characteristics, which the research project's participants established as key to meeting their engineering function's needs.

I first acknowledge my major advisor, Dr. Kenneth E. Case, without whose decade-long patience, guidance, and scholarly inputs this research project would have been a series of "special causes" and not "locked down tight." Thank you very much Dr. Case. You made it happen.

I also extend gratitude to my doctoral committee -- Dr. William Kolarik, Dr. David Pratt, and Dr. Ramesh Sharda for their invaluable support and direction - thank you committee.

I am also very grateful for the significant help given me by Dr. Terry R. Collins, Assistant Professor, Department of Industrial Engineering, Texas Tech University and Dr. Leva K. Swim, Director, Decision Support, Integris Health, Oklahoma City, Oklahoma – these I.E. scholars and practitioners patiently offered comments and suggestions throughout the project – from start-to-finish. Thanks Drs. Collins and Swim.

To the major participants in this research, a big "Thank you". First, my gratitude is given to Dr. Wayne Jones, Chief, Science and Engineering Division, Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma for significantly facilitating the data collected from the federal government sector. Next, a tremendous Thank you" is shouted for Mr. John Crutchfield, Chief, Industrial Engineering Department, Boeing Integrated Defense Systems, St. Louis, Missouri for sponsoring the research in his division. Thank you manufacturing sponsors.

I also acknowledge the help given me by colleagues at the University of Central Oklahoma – a special thank you must go to Drs. Bob Curley, Warren Dickson, Saba Bahouth, Jerry Allison, and Tim

Bridges. Finally, huge thanks are extended to Dean Tom Boyt of the College of Business. Dr. Boyt stood by me and offered significant intellectual and the financial support of the College at crucial periods to help "jump start" the research. Thank you also staff and teaching assistants for your help. Thanks, UCO.

Thanks are also extended to the faculty members from industrial engineering academic departments of the Oklahoma State University, University of Oklahoma, University of Arkansas, University of Missouri, Kansas State University, Wichita State University, University of Kansas, Louisiana State University, New Mexico State University, Texas Technical University, and Texas A&M University. Special thanks also go to those graduate and undergraduate students, who participated from the School of Industrial Engineering, University of Oklahoma. Thanks academicians and student sponsors.

I thank a dear friend for her support over the years, Dr. Suzanne Murphy, whose persistent question, "How's the dissertation going?" was the right stick at the right time. Thank you for your concern and prayers.

I thank my close family for giving so much help over the years: daughters Lori and her husband Dan Lieberman; daughter, Traci; mother-in law, Mary Pinto and father, Ferdinand Hartmann.

Last but not at all the least, a special thank you is given to my closest "Amiga" and spouse for the past thirty-five years, Carol. You are beside me every step in the dissertation process and in so doing sacrificed many current desires for our future in academia. Thank you very much, Carol. Now, its my turn to cook dinner!

Thank you "Team".

Thank you, God, it has begun..., !

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES ... ix

LIST OF FIGURES ... x

Chapter 1. Introduction ... 1
- 1.1 Introduction ... 1
- 1.2 Statement of the Problem ... 4
- 1.3 The Purpose of the Research ... 4
- 1.4 Sub-objectives of the Research ... 4
  - 1.4.1 Sub-objective 1 ... 4
  - 1.4.2 Sub-objective 2 ... 4
  - 1.4.3 Sub-objective 3 ... 5
  - 1.4.4 Sub-objective 4 ... 5
  - 1.4.5 Sub-objective 5 ... 5
- 1.5 List of Definitions ... 6
- 1.6 Conclusions ... 9

Chapter 2. Literature Review ... 11
- 2.1 Introduction ... 11
- 2.2 Contemporary Dynamics in Engineering Education ... 13
- 2.3 Higher Education as a System ... 15
- 2.4 Factors Shaping Higher Educational Outcomes ... 16
- 2.5 Institutional Review ... 19
- 2.6 Baldrige National Quality Award and Higher Education ... 20
- 2.7 Quality Review: An Example ... 20
- 2.8 Stakeholder Value ... 21
- 2.9 Stakeholder ... 21
- 2.10 Quality in Higher Education ... 22
- 2.11 New Educational Forms ... 23
- 2.12 Changes in Higher Education ... 23
- 2.13 Changes in Learning Styles and Research Approaches ... 24
- 2.14 Education and Networks ... 25
- 2.15 Dimensions of Technology and Quality ... 27
- 2.16 The "New" Organizational Environmental Dimensions of the Industrial Engineer ... 27
  - 2.16.1 Organizational Evolution ... 28
  - 2.16.2 Human Relations Evolution ... 29
  - 2.16.3 Engineering Skills Development ... 30
  - 2.16.4 The Industrial Engineer in the Organization ... 30
- 2.17 Methods for Evaluating and Measuring Stakeholder Judgments ... 38
  - 2.17.1 Single Attribute Analysis ... 39
  - 2.17.2 Multiple Attribute Analysis ... 40
  - 2.17.3 Analytical Hierarchy Process Modeling ... 41
  - 2.17.3.1 Hierarchy of Academic Engineering Requirements ... 45
- 2.18 Requirements for a Decision Method ... 47
- 2.19 Summary ... 47

Chapter 3. Methodology 49
3.1 Introduction 49
3.1.1 Sub-objective 1 50
3.1.2 Sub-objective 2 50
3.1.3 Sub-objective 3 50
3.1.4 Sub-objective 4 50
3.1.5 Sub-objective 5 51
3.1.6 Alignment 51
3.2 Research Plan 51
3.2.1 Step 1: Develop Questions about Goals Alignment between the Stakeholders 53
3.2.2 Step 2: Develop a Survey Research Plan. 54
3.2.3 Step 3: Develop Requirements for Academia, Employer, and Student Stakeholders 55
3.2.4 Step 4: Develop an AHP Hierarchy. 56
3.2.5 Step 5: Develop a Research Instrument Based Upon the AHP Hierarchy. 56
3.2.6 Step 6: Pretest the Research Instrument. 56
3.2.7 Step 7: Execute the Survey Research. 57
3.2.8 Step 8: Gather Data from the Survey Instruments. 57
3.2.9 Step 9: Prepare the Data for Insertion into an Expert Choice© PC Application. 57
3.2.10 Step 10: Develop hypotheses about the alignment of goals between the stakeholders. 57
3.2.11 Step 11: Analyze Each Research Instrument. 58
3.2.12 Step 12: Develop and Execute Statistical Analyses. 58
3.2.12 Step 13: Draw and State Conclusions. 58

Chapter 4. Development of the Methodology 59
4.1 Introduction 59
4.2 Discussion of the Research Phases 60
4.3 Phase I 62
4.3.1 Preliminary discussions: 62
4.3.2 Phase 1: Manufacturing Focus Groups 63
4.3.3 NGT and Affinity Session 68
4.3.4 Academic Focus Groups 71
4.3.5 Group Hierarchy Judgments. 72
4.4 Summary and Follow-on Actions to Phase I 72
4.5 Phase II 74
4.5.1 Phase II Survey: Academic review 75
4.5.2 Phase II Survey: Conclusion 76
4.6 Phase III 85
4.7 The Data 88
4.7.1 Analytical Hierarchy Process 89
4.7.2 The Analytical Hierarchy Process Explained 89
4.7.2.1 Method 89
4.7.2.2 Determining the Consistency Ratio. 92
4.8 A Summary of the Methods to Answer the Sub-objectives of the Research 93
4.9 Statement of the Hypotheses 95
4.9.1 Hypothesis 1.0 98
4.9.1.1 Hypothesis 1.1 98
4.9.1.2 Hypothesis 1.2 98
4.9.1.3 Hypothesis 1.3 98
4.9.1.4 Hypothesis 1.4 98
4.9.2 Hypothesis 2. 0 98
4.9.2.1 Hypothesis 2.1 98
4.9.2.2 Hypothesis 2.2 98
4.9.2.3 Hypothesis 2.3 99
4.9.2.4 Hypothesis 2.4 99
4.9.3 Hypothesis 3. 0 99
4.9.3.1 Hypothesis 3.1 99

4.9.3.2 Hypothesis 3.2 99
4.9.3.3 Hypothesis 3.3 99
4.9.3.4 Hypothesis 3.4 99
4.9.4 Hypothesis 4.0 99
4.9.4.1 Hypothesis 4.1 99
4.9.4.2 Hypothesis 4.2 99
4.9.4.3 Hypothesis 4.3 99
4.9.4.4 Hypothesis 4.4 100
4.9.5 Hypothesis 5. 0 100
4.9.5.1 Hypothesis 5.1 100
4.9.5.2 Hypothesis 5.2 100
4.9.5.3 Hypothesis 5.3 100
4.9.5.4 Hypothesis 5.4 100
4.9.6 Hypothesis 6.0 100
4.9.6.1 Hypothesis 6.1 100
4.9.6.2 Hypothesis 6.2 100
4.9.6.3 Hypothesis 6.3 100
4.9.6.4 Hypothesis 6.4 100
4.10 Assumptions and Limitations 101
4.11 Conclusions 102

Chapter 5. Application Results and Analyses 103
5.1 Introduction 103
5.2 Survey results 104
5.2.1 Analyses of the Results 110
5.3 Univariate Tests of the Sampled Data. 112
5.3.1 Methodology 112
5.3.1.1 Independent t-Test 112
5.3.2 Non-Normality 113
5.3.2.1 Goodness-of-Fit Tests for Statistical Distributions 114
5.3.2.2. Results of the Anderson-Darling Test. 117
5.3.2.3 Conclusion of Goodness of Fit Tests 119
5.3.3 Unequal Variance Assumption. 119
5.4 Multiple Comparisons. 121
5.4.1 Games-Howell "multiple comparisons" procedure. 121
5.5 Conclusions 122

Chapter 6. Conclusions and Recommendations 125
6.1 Introduction 125
6.2 Summary of Methods 125
6.3 Results and Conclusions 127
6.3.1 The Sub-Objectives 128
6.3.2 Research Concerns 131
6.4 Contributions 132
6.5 Limitation of Research 134
6.6 Recommendations 135

References 136

Appendixes 142

Appendix 1 – Oklahoma State University Institutional Review Board Form for Research Involving Human Subjects 143

Appendix 2 – Structured Interview Questions 147

Appendix 3 – Research Phase I Review 151

Appendix 4 – Research Phase II Review 168

Appendix 5 – Survey Pretest in Research Phase II Review 184
Appendix 6 – Phase III Pretest 254
Appendix 7 – Phase III Pretest – Version 2.0 270
Appendix 8 – Final Survey Pretest 286
Appendix 9 – Final Survey Package: Oklahoma City Air Logistics Center 301
Appendix 10 – Final Survey Package: Boeing Integrated Defense Systems 315
Appendix 11 – Phase III Cover Letter: Academician Sample 330
Appendix 12 – Student Sample Informed Consent Letter 335
Appendix 13 – MINITAB©, Version 13.0 Analyses 338
Appendix 14 – Phase III Academician Status Record 359

LIST OF TABLES

Table Page

1.1 Freeman's (1984) Stakeholder Classification ... 8
2.1 Structure of the Literature Review ... 11
2.2 Boyer Commission (1998) Goals for Higher Education ... 23
2.3 Summary of the Boyer Commission's Report (1998) Findings ... 24
2.4 Mayadas' (1997) Five Pillars of Alternative Learning Networks ... 26
2.5 Summary of Personal Interviews ... 32
2.6 The Saaty (1986) Nine Point Scale of Priority Judgments ... 43
2.7 Summary of Saaty's (1985) Analytical Hierarchy Process ... 45
2.8 Modified Hierarchy: Academic Engineering Requirements for Undergraduates ... 46
2.9 Fahnri and Spatig (1990) Taxonomy of Decision Criteria ... 47
3.1 Research Plan ... 49
3.2 Summary of Saaty's (1985) Analytical Hierarchy Process Defined for the Research Project ... 52
4.1 Research Plan: Development of the Methodology ... 59
4.2 Affinitized Results of the Nominal Group Technique Session at OC-ALC, 18 Dec 02 ... 73
4.3 Hierarchical Model of Characteristics Expected by Employers in the Ideal Graduate-level Industrial Engineer Following Graduation ... 80
4.4 Definitions Determined by Manufacturing Expert Panel ... 81
4.5 Judgment Matrix [Empirical Research Data] ... 90
4.6 Normalized Judgment Matrix [Empirical Research data] ... 90
4.7 Normalized Judgment Matrix with its Simple Average Priority Vector [Empirical Research Data]. ... 91
4.8 Normalized Judgment Matrix with its Priority Vector: Simple and Geometric [Empirical Research Data] ... 91
4.9 Weighted Sum Vector Data [Empirical Research Data] ... 92
4.10 Random Index Table of Values ... 93
4.11 Summary of Hypotheses ... 97
5.1 "Respondent" Population Survey Results ... 104
5.2 Global Priorities for Respondents ... 105
5.3 Undergraduate Student Sample Survey Results ... 106
5.4 Graduate Student Sample Survey Results ... 107
5.5 Manufacturing Sample Survey Results ... 108
5.6 Academic Sample Survey Results ... 109
5.7 Independent t-test of the Sample Data ... 113
5.8 Anderson-Darling Test ... 116
5.9 D'Agostino and Stephens (1986) Tables ... 117
5.9.1 Research Test Using Anderson-Darling ... 117
5.9.2 Anderson-Darling Statistic versus Power Statistic Test for Normality ... 118
5.10 Test of Equal Variances ... 120
5.11 Games-Howell Test Results ... 123
5.12 Summary of Hypotheses ... 124
6.1 Global Priorities for Respondents: Non-normalized ... 131
6.2 Global Priorities for Respondents-Normalized ... 131

LIST OF FIGURES

Figure		Page
1.1	Triangular Perspectives of the "Stakeholder" Populations	3
2.1	The Literature Review Map	12
2.2	Generic Analytic Hierarchy Process Model	42
3.1	Model of Research Comparisons	53
4.1	Model of Research Instrument Development and Data Collection	61
4.2	Research Phase I Model	62
4.2.1	Briefing: Introduction	64
4.2.2	Briefing: Research Question	64
4.2.3	Briefing: Project Overview	65
4.2.4	Briefing: Project Stages	65
4.2.5	Briefing: NGT Research Question	66
4.2.6	Briefing: Unclassified Ideas Model	69
4.2.7	Briefing: Affinitization Diagram, Part 1	70
4.2.8	Briefing: Affinitization Diagram, Part 2	70
4.2.9	Briefing: AHP Model, Part 1	71
4.2.10	Briefing: AHP Model, Part 2	71
4.3	Research Phase II Model	75
4.4	AHP Models: "Accepted", Theory, and Phases I and II	84
4.5	Research Phase III Model	87
4.6	Research Phase III Output Model	88
4.7	Triangular Perspectives of the "Stakeholder" Populations with Sub-objectives	96
5.1	Dotplot of Sample Data for Technical, Managerial, Social and Political Characteristics	110
5.2	Grouped Dotplot of Sample Data	111

Chapter 1. Introduction

1.1 Introduction

Manufacturing and service organizations generate outputs to satisfy the needs of the consumer whose perceptions and judgments are shaped by an environment of political, economic, social, and technological change. Products and service outputs result from processes supported by these companies' engineering employees, who may be also represented as an "output" from a diverse set of originating sources. Such "sources" can be the "general workforce," direct accession from high school, or graduates of higher education engineering programs.

As the source for granting degrees to industrial engineering undergraduate and graduate-level students, engineering higher education is motivated to adapt to the manufacturing and service consumer's changing requirements for an educated engineering employee. This motivation may be partially based on institutional and departmental-level accreditations, a critically important concern for stakeholders in institutions and the institutions' engineering departments. While an accreditation is alone significant and requires an institution/department to plan, collect, archive, and employ feedback data representing the explicit needs of the stakeholder in the output of academic programs, there also exists other significant "drivers" [motivators] acting upon an institution to better understand the consumer. These drivers may be generally provoked from an institutional appreciation for a singular body of knowledge; a recognition of an expanding market for "on demand," on-line education; and, finally, efforts to incorporate quality, technology, and a diversity of institutionally unique program outcomes demanded by the consumer into engineering programs.

Earlier scholarly research of engineering education revealed that the engineering discipline, and in particular industrial engineering, "...has problems, such as a theoretical approach to problem solving, insufficient understanding of real-life problems, and poor communication skills" (Koksal & Egitman, 1998). Further, engineering education research has not been discriminant in modeling the graduate and undergraduate consumer. A conclusion may be that an imprecise definition of the term "student" [graduate or undergraduate] could affect the process of educating the graduate-level industrial engineer such that their subsequent presentation as a candidate for the workforce community is not "aligned" with that community's needs.

In attempting to satisfy institutional accreditation and the needs of various consuming stakeholders, previously mentioned, university-level academic departments develop "linkage processes" to effect collaboration and cooperation with stakeholders (The Green Report: Engineering Education for a Changing World, 1994; Lang et al., 1999). However, anecdotal evidence from interviews conducted by the author with members of the Industrial Engineering Department's Advisory Board, University of Oklahoma suggests that linkage processes, for example departmental advisory boards and self-reported surveys of a program's graduates, result in technically biased expectations for reasons beyond the scope of this research. However, the same anecdotal evidence also suggests that advisory boards and surveys tend to generalize expectations from non-technical factors such as a graduate's capabilities in communication, inter-personal relationships, management, and "...other duties as required." Indeed, there may be a universe of needs the stakeholders would seek in an engineering program's graduate-level graduate given the program had access to unlimited resources. However, a systematic process to explicitly define a hierarchy of needs with dependencies and priorities spanning the technical and non-technical components of an engineering program may not be well understood by a program's stakeholders.

Research is needed for a better understanding of and a methodological process for assessing the judgments of stakeholders in the interdependent system of educational institutions, students, and consumers of graduates, if a graduate-level industrial engineer is to possess a skills set closely aligned to the needs of the consumer upon their graduation.

Therefore, several questions are provoked: "What if the process of understanding alignment began at the manufacturing stakeholder level and proceeded to meet industrial engineering higher education at the level of the graduate student - a demand-pull context?"; or "What if industrial engineering higher education and its student populations were to make comparative judgments through the same skills hierarchy and prioritization instrument that was previously defined by the manufacturers?" An answer to these questions may be suggested by the following question: "If at a given point in time we knew the skills each stakeholder sought in graduate-level engineering graduates, would we witness an alignment or a lack of alignment in their skills expectations; and how similar are these stakeholders' needs sets? The goals for each stakeholder would appear to be synthesized in the following question and Figure 1.1:

"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"

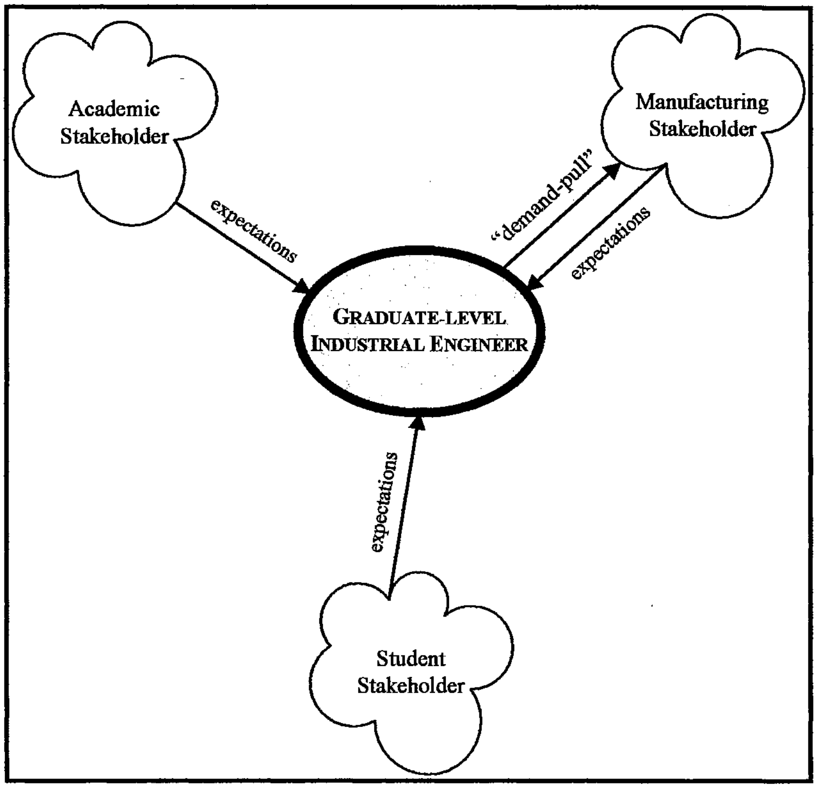


Figure 1.1 Triangular Perspectives of the "Stakeholder" Populations

In summary, the current research project seeks to answer those questions by presenting a methodological approach to define an expert manufacturing panel's set of graduate-level industrial engineering skills requirements. Next, the research employs the proposed methodological approach in empirical research designed to define a hierarchy of these requirements through a consensus process known as the Nominal Group Technique; and then to develop a set of comparative weights of the requirements. Nest, the research addresses the needs of manufacturing stakeholders typical of industrial businesses hiring industrial engineers. The research also assesses the needs of an industrial engineering higher education stakeholders at the graduate level by collecting data from surveys of academicians, graduate students and senior students enrolled in a graduate-level industrial engineering course.

1.2 Statement of the Problem

Higher education's engineering programs and their stakeholders' requirements should be aligned to provide graduate-level engineers who possess the requirements of internal and external stakeholders. Previous research into a demand-pull methodology for assessing industrial engineering skills alignment at the graduate-level is unknown.

1.3 The Purpose of the Research

The objective of this research project is [to]

> *Model a methodology or sequential approach for measuring the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers' skills meeting the requirements of selected stakeholders.*

The study has been designed using the methods for conducting observational, descriptive survey research, because it is important to develop an understanding about the current status of goals alignment for a representative sample of stakeholders and then to ultimately generalize to a broader set of consumers of industrial engineering graduate-students.

1.4 Sub-objectives of the Research

To complete the research project, the objective was further stratified into the following sub-objectives:

1.4.1 Sub-objective 1

Develop a methodology to understand the needs of a stakeholder in the industrial engineering graduate student and to understand the process of obtaining a consensus of opinion about their needs.

1.4.2 Sub-objective 2

Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes. A demand-pull process should clearly understand the skills and knowledge requirements, the hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

1.4.3 Sub-objective 3

Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes. The demand-pull process should have the academicians understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationships among the requirements, and the weights [priorities] given these skills and knowledge.

1.4.4 Sub-objective 4

Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes. The demand-pull process should have the students understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

1.4.5 Sub-objective 5

Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.

1.5 List of Definitions

Selected key terms and phrases used in this research are denoted by the italicized word or phrase given in the following alphabetized list:

Alignment: There are as many definitions of "alignment" as there may be studies of this concept. A tested definition is found in the 2001 Education Criteria for Performance Excellence. A paraphrased definition is as follows, "[Alignment is] …a linkage of organizational goals and measurements enabled to satisfy all stakeholders" (Baldrige National Quality Program, 2001). In this research, "alignment" builds upon the Baldrige criteria and is defined by the statistical similarity of the inter-stakeholder comparisons of the analytical hierarchy process comparative judgments, e.g., the alignment between the manufacturers and the academicians.

Assessment: An established, documented methodology to evaluate the organization's alignment and the means to propose modifications to the goals of the process being measured (Baldrige National Quality Program, 2001). In this research, the definition is modified to include departmental advisory committees, and departmentally initiated employer surveys and alumni surveys.

Control: Any steps intended to measure, compare, and adjust outcomes from a process.

Expert panel – academic: An assembled group representing higher education. While there are a large number of definitions of a higher education expert, the following are assumed as defining "expert":

- The individual has earned the terminal Ph.D. in an engineering discipline; and
- The panel member has been directly involved with the engineering department's business advisory committee or similar such committee regardless of a specific name.

Expert panel – manufacturing: An assembled group representing NAICS-coded manufacturing companies. While there are a large number of definitions of a manufacturing engineering expert (Babcock, 1991, pp. 218-219) the following are assumed as defining "expert":

- The individual is serving in a management position;
- The panel member has at least five years previous engineering experience; and
- The panel member has witnessed and provided input to at least one fiscal budget cycle.

Higher education: Any regionally accredited post-secondary institution offering degrees from the baccalaureate through the doctoral (Midbo, Otis, and Feorene, 1991).

Innovation: The process of defining new relationships and/or new applications for old solutions (Katz, 1998).

Input: A measurable resource introduced to a value-conversion process. (See definition of "value-conversion," this section).

Knowledge: Information cognitively assembled into mutually supportable groups.

Management: A key characteristic of an engineer, it is an ability to get things done by planning, organizing, directing, and controlling others in the organization (defined by the expert group of manufacturers in a Nominal Group Technique meeting, 17 December 2002, OC-ALC, Tinker AFB, OK as facilitated by the Author).

Methodology: A systematic process of moving from the unknown towards the known as framed by the research question (Render & Stair, 1999).

Motivation: The energizing influence upon and within an individual that triggers a drive to act toward goals, which is sustained and/or modified by feedback from the results of the action (Steers & Porter,1991, p. 6).

Outcomes: Otherwise given in this research as "stakeholder value", outcomes are the stakeholder's desired expectations. They are a set of requirements, which is something that follows as the result of a consequence (Woolf, 1973) by which a stakeholder measures their personal alignment.

Output: A measurable conclusion of a process.

Phase: One of four divisions of the research methodology.

P.E.S.T.: An acronym denoted by the terms, *political, economic, social,* and *technological.* These terms characterize generally accepted forces acting upon a system (Porter, 1985).

Political: A key characteristic of an engineer, it is an ability of an engineer to enhance his or her power, build a power base, and to establish right connections in the organization (defined by the expert group of manufacturers in a Nominal Group Technique meeting, 17 December 2002, OC-ALC, Tinker AFB, OK as facilitated by the Author).

Process: Any task or action that impacts customers or stakeholders. "A systematic series of actions directed to the achievement of a goal" (Juran, 1989).

Skill: The ability to accomplish a task resulting from knowledge or experience. Some skills are cognitive (such as mathematics, marketing, accounting, and so on), while other skills are noncognitive (interpersonal relations, teamwork, motivating others, and so on) (Badawy, 1995)

Social competence: A key characteristic of an engineer, it is an ability of an engineer to work with, understand, communicate with and motivate other people, both individually and in groups (defined by the expert group of manufacturers in a Nominal Group Technique meeting, 17 December 2003, OC-ALC, Tinker AFB, OK as facilitated by the Author).

Stakeholder: An individual or group of people who have a demand or need that must be addressed in the output of the value-added process. Also, the recipient, intended or not by owners of the process, of the output from a valued-added process, such as the supplier to a manufacturing company, the manufacturing company, and the customer of the manufacturer. Table 1.1 is Freeman's (1984) classification [of *stakeholder*] in a commercial context. To Freeman's classification, the term, *student* and *academia* are added by the author for the current research:

Table 1.1 Freeman's (1984) Stakeholder Classification

Stakeholder Category	**Possible Near-Term Measures of Expectations**	**Possible Long-Term Measures**
Customers	Sales New customers New products & services	Sales growth Customer turnover Price stability
Suppliers	Cost of material Delivery time Inventory Availability of material	Trends in costs, delivery, inventory New idea acceptance
Financial Community	Earnings per share Stock prices Return on investment	Trends Trust Confidence
Employees	Number of suggestions Productivity Number of grievances	Number of promotions Turnover

Student: Unless otherwise qualified in this research, a student is an undergraduate or graduate classified person, who is currently enrolled fulltime in a graduate industrial engineering program - higher education. Further, the student connotes, in the present context, the primary input to a value conversion process to be output for consumption by a stakeholder community.

Technical professional: An engineer, accredited/certified or not, in a paid position as a self-employed consultant or organization employee, who subscribes to a recognized body of knowledge (Babcock, 1991, pp. 140-43).

Technical skills: The engineer's specialized knowledge and their acquired expertise used to carry out particular [engineering] techniques and procedures (defined by the expert group of manufacturers in a Nominal Group Technique meeting, 17 December 2002, OC-ALC, Tinker AFB, OK as facilitated by the Author).

Value: An economic benefit, it is a quality, intrinsic or extrinsic that serves as a measure of quantifiable or qualifiable change in an input during conversion to an output (Wheelen & Hunger, 1998).

Value Conversion: The process of changing the economic benefit [to a stakeholder] of a resource from an input stage to the point the resource is classified as an output.

Virtual commerce and the virtual organization: Any commercial business, non-profit/not-for-profit organization and public sector activity that defines its connectivity patterns (internal and external) primarily in an electronic medium (Author).

1.6 Conclusions

This research models and compares the requirements of selected stakeholder stakeholders - the manufacturer, industrial engineering academic and the undergraduate and graduate industrial engineering student – to clarify the significance of a mutual alignment of stakeholder requirements. This understanding is a step towards improving stakeholder decision-making. Research literature is limited addressing the higher education, institutional decision-making process associated with the curricular prioritization of graduate-level engineering courses with respect to the graduate engineering student stakeholders. Therefore, Chapter 2 discusses contemporary forces of change in engineering higher education and the environment that may shape the mindset of the industrial engineering student. Chapter 2 concludes with a review of the quantitative analysis models employed for multi-attribute decisions. Chapter 3 presents the methodology to answer the research objective and sub-objectives. Chapter 3 then discusses confounding issues in developing stakeholder consensus of opinion and assessing comparative judgments. Chapter 4 operationally presents the research methodology in a discussion of the procedures from a representative sample of manufacturers, industrial engineering departments, and senior and graduate-level students currently enrolled in the industrial engineering major. Chapter 4 then presents a discussion of the quantitative analyses. Chapter 5 illustrates the results and analyses of the sampled data. Chapter 6 argues the conclusions, contribution, limitations of research, and recommendations for the future.

Chapter 2. Literature Review

2.1 Introduction

Higher education's engineering programs and their stakeholders' requirements should be aligned to provide graduate-level engineers whose skills meet the requirements of internal and external stakeholders. As previously stated, previous research into a demand-pull methodology for assessing engineering skills alignment at the graduate-level is unknown. Therefore, the purpose of this chapter is to investigate the research problem from several perspectives: the stakeholder, the higher educational environment, and the industrial engineering graduate student. The literature, then, develops around the question presented in Chapter 1,

> *"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"*

Table 2.1 illustrates the structure of Chapter 2 and depicts those sections relevant to the discussion of the terms lists in the column "Literature Review Terms." Figure 2.1 then maps this chapter's literature investigation process as an integrated methodology of discovering extant literature on the research problem. (See Section 1.2).

Table 2.1 Structure of the Literature Review

Literature Review Term	Relevant Sections in Chapter 2
Environment	{2.2 through 2.7 and 2.10 through 2.16}
Stakeholder	{2.3, 2.9}
Controls	{2.4, 2.5, 2.6, 2.7}
Value	{2.8}
Industrial Engineer	{2.16}
Analytic Models	{2.17}

Initially, this chapter briefly discusses contemporary forces of change in engineering higher education. These forces may result from the pursuit for an improvement of quality and from the changes in the distribution of the process of providing the educational experience as a result of technology. Secondly, this chapter then addresses the environment that may shape the mindset of the industrial engineer. This discussion views the industrial engineer as functioning in a changing set of organizational relationships and demands for their engineering talents/skills.

Third, the chapter concludes with a review of the quantitative analysis models employed for multi-attribute decisions: the structure of the decisions suggested by the Statement of the Problem of this research. Principal discussion centers on the analytical hierarchy process (AHP) model and the AHP methodology.

2.1.1 The Literature Review Map

The Chapter 2 literature review generally follows a process as illustrated in Figure 2.1. In this figure, the terms are denoted as previously defined in Chapter 1. The process is modeled upon previous resource conversion, "value-added", literature reported in many textbooks and is based upon Porter's (1985) research into the value-added process model.

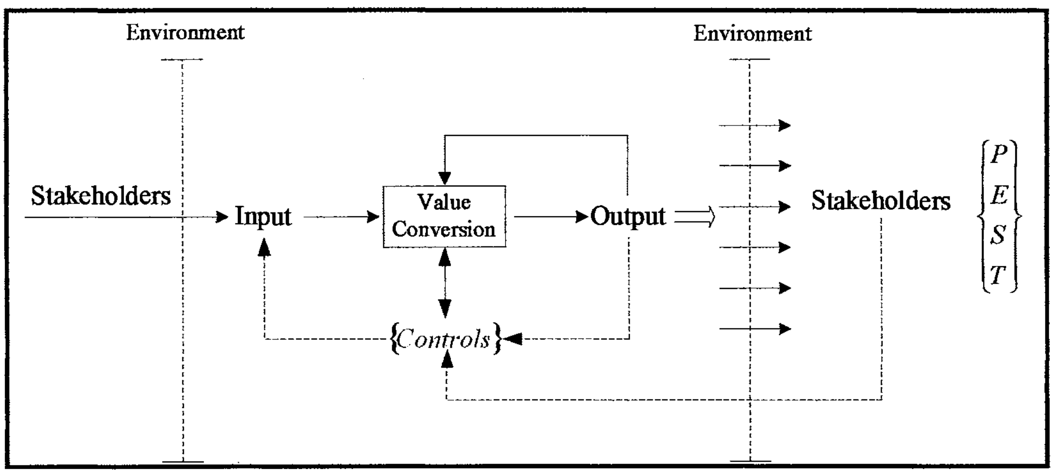


Figure 2.1 The Literature Review Map

Chapter 2 considers the stakeholders as inputting knowledge and skills requirements [in graduate-level industrial engineers] through an environmental filtering layer. The literature supporting this assertion is subsequently presented. One stakeholder is the graduate student. He or she enters as an "input" to a value-conversion process in higher education, which attempts add to their initial knowledge and skills set. The student, "output", then exits the higher educational system through another environmental filter that expects a difference between the input and output stages. Feedback loops may be present and the student may have "something to say" about their educational experience. Surrounding the student and other stakeholders are the forces of *politics, the economy, society,* and *technology*, also known as P.E.S.T. (See "P.E.S.T." previously defined in Chapter1, Section 1.5).

2.2 Contemporary Dynamics in Engineering Education

In 1994, the American Society for Engineering Education released "The Green Report: Engineering Education for a Changing World" in which it was concluded that "...the engineer will play a significant role in,...a time of revolutionary [technological] change" (The Green Report: Engineering Education for a Changing World, 1994). This conclusion is shared internationally as well.

In 1996, The Institution of Engineers, Australia (IeAust) released the results of an eighteen month long review of Australian engineering education (The Institution of Engineers, 1996). The IeAust study was a multidisciplinary, multi-stakeholder methodological approach to Australian engineering needs and the products of the Commonwealth's engineering schools. Steering teams resembled those employed in the conduct of the Green Report (1994) and included task forces to study the interfaces with students, industry, professions, educational programs, institutional policies, and the "Community." In the Study's findings, it was stated that,

> "An initial finding of the Review, confirmed in subsequent consultations, was the need for a culture change in engineering education, ultimately to extend throughout the profession. The present emphasis placed on engineering science resulting in graduates with high technical capability, has often acted to limit their appreciation of the broader role of engineering professionals. Graduates must understand the social, economic, and environmental consequences of their professional activities if the profession is fully to assume its expanding responsibilities." (The Institution of Engineers, 1996, p. 2).

The IeAust Report also cited similar studies then ongoing in the United States, Germany, Canada, Brazil, and the United Kingdom. It stated that very similar conclusions had also been reached in these international studies. (The Institution of Engineers, 1996, pp. 82-90)

Because the primary source of an educated and registered engineering community is higher education, a study of the alignment of engineering providers and consumers would appear to be required as a consequence of international studies looking at the future of engineering (The Joint Task Force on Engineering Education Assessment, 1996).

Higher education also provides for the needs of stakeholders - consumers, such as students, chartered communities (incorporated cities), and various commercial entities in a dynamic environment like that experienced by product and service companies (Benefield, Trentham, Khodadadi, & Walker, 1997; Todd, et al., 1993). As a result, the stakeholder is characterized by a knowledge and skills needs that, as inputs to a value-adding process, add to the complexity of simultaneous alignment of expectations.

A basic plan linking the educational institution, the student, and the stakeholder - consumer may be the *academic curriculum*. The academic curriculum is a form of business plan that constitutes an agreement between the educational institution and the student regarding the manner, timing, and sequence of "course products", whose successful completion is required for graduation (Carey, 1998). Traditionally, these curricular plans find support and direction in the institutional accreditations and departmentally specific accreditations (Leepatanapan, 1997). Similarly, the institution's external stakeholders are important for shaping and suggesting a direction for the engineering curricula of the institution (ABET, 2002).

Consumers of student graduates have interests in the outcomes the institution produces: specific courses and certain people skills that "cut across" individual courses, such as oral and written communications, computer competency, self-initiative, goals-setting, team work, ethical behavior, among others (Todd et al., 1993). Capturing these "interests" in a systematic process may lead to a better definition for the curricula.

Methods to assess the needs of the consumers of student graduates depend upon the specific consumer and, perhaps, the specific student, whether they are a graduate or the student in matriculation. Such methods as surveys of alumni, employers, and accreditation bodies uncover the similarities and gaps between the expectations of educational institution, students, and employer-consumers (Jack, Stephens, & Evans, 2001; Johnson, 1998; Puerzer & Rooney, 2002). Formulating a process to operationalize the collective expectations of stakeholders is a challenge.

Engineering education has a mandate for assessment plans that address stakeholder requirements (ABET, 2002; The Joint Task Force on Engineering Education Assessment, 1996). However, it is not clear that there is a generally accepted method for assessing the needs of universities and stakeholders. Manufacturing and service organizations generate outputs to satisfy the needs of the consumer in contemporary environments shaped by political, social, economic, and technological forces of change (Porter, 1985; Leepatanapan, 1997; Lang, Cruse, McVey, & McMasters, 1999). Products and services result from processes supported by manufacturing and service companies' employees, who represent the output from a diverse set of originating sources, such as the "general workforce", direct accession from high school, or the product of higher education (Joiner, 1994; Todd, Sorensen, & Magleby, 1993; Hillenmeyer, 1996).

As a primary source for educating today's personnel resources, engineering higher education should be aware of and adapt to the manufacturing and service consumer's changing requirements for an educated employee (Lang, et al., 1999). This motivation may be partially based on the institution's accreditations, which require the institution to plan, collect, and employ data representing the explicit needs of the consumer in academic programs. Other "drivers" for a better understanding of the consumer originate from: a particular discipline's singular body of knowledge; (Sounderajan, 2002) an institution's recognition of an expanding market for "on demand', on-line education produced by commercial entities (Bourne, Brodersen, et al., 1996); and quality, technology, and program outcomes demanded by the consumer. Koksal and Egitman (1998) noted that earlier research revealed that engineering, and in particular industrial engineering, "...has problems such as a theoretical approach to problem solving, insufficient understanding of real-life problems, and poor communication skills" (Koksal & Egitman, 1998).

By attempting to meet the obligations of its institutional accreditation and the needs of a diverse consuming stakeholder (student, marketplace, political communities), universities attempt to develop linkage mechanisms to effect collaboration and cooperation with stakeholder communities (The Green Report: Engineering Education for a Changing World, 1994; Lang, et al.,1999).

2.3 Higher Education as a System

Higher education (HEd) is a process of creating innovation and change to meet the expectations of a variety of stakeholders (Bourne, Brodersen, Campbell, Dawant, & Shiavi, 1996; Dill, Massy, Williams, & Cook, 1996; Hillenmeyer, 1996; Regan & Sheppard, 1996). For example, individual people, chartered communities and commercial entities are affected by HEd and are interested in the results of HEd processes. Stakeholders tend to define HEd process results along a continuum ranging from "success" to "failure". Outcomes may be generally classified in several ways. For example, one or more of the following categories have been found to be relevant for research institutions: institutional and departmental accreditations, enrollment levels, graduation rates, student retention, nationally standardized examination results, research and grant funding received, peer-reviewed publications, consultancy contracts, faculty evaluations, and/or numbers of external entity participants in "university career days" (McMillan, 1998). Further, a stakeholder can develop models and systems to track the differences between expected outcomes in comparison to goals, changes in the results over time, or the relationships between lower-level outcome(s) and a macro-set of institutional outcomes. Since stakeholder perceptions and expectations are individual, satisfying every stakeholder can result in conflicting goals for HEd (McMillan, 1998; Shelnutt & Buch, 1996). It may then be important for the outcome of the process that engineering principles of control, evaluation, scheduling, optimization, and quality are used in the improvement of the decisions made by stakeholders of the educational system.

2.4 Factors Shaping Higher Educational Outcomes

Stakeholders recognize in varying degrees "factors" that may moderate and influence the outcomes of a higher educational process, i.e., the "environmental filtering" discussed in chapter2, section 2.1. Technology, quality, and industry-educational collaborations are factors, which can effect change in academic pedagogy. In recent years, however, technology more than any other factor has influenced traditional educational delivery systems, course management processes, and academic time scales (Regan & Sheppard, 1996). However, whether or not technology adoption by higher education translates into a "better" graduate-level engineer is subject to conjecture and is beyond the scope of this research.

Nevertheless, in recent years academic service mechanisms for distributing and consuming higher education have evolved with technological improvement and stakeholders have taken a more "active" role in the self-selection of curricula and accessing academic courses (See also Chapter 2, Section 2.14, 2.15).

While technology has always been a part of higher education, either from a rhetorical study, as a silent partner in academic delivery, or as a model for scientific and applied research, the study of the impacts of technology upon higher education appears to receive "punctuated" attention with stakeholder input, such as institutional accreditation (Dill, Massy, et al., 1996). This means that stakeholders may motivate the institutional bias towards technological innovation and an adoption of quality principles as a component of *control* (See Figure 2.1).

From the review of the literature thus far as from the definition of *control* as given in section 1.5, research was then conducted into literature researching the required elements in the skills set of the engineer. Earlier, Leepatanapan (1997) reported adopting a set of manufacturing engineering characteristics given by the Society of Manufacturing Engineers in 1994 as basis for assessing the hierarchy of skills in Thai engineers and Thai manufacturers in order to suggest a curriculum for undergraduate engineering. This research developed curricula, which moderated the weight of technical programmatic concentration in favor of an increased qualitative component of the engineering. Benefield, et.al. (1997) reported quality improvements in engineering educational programming resulting from surveys of selected student and industry respondents. Their research ranked sixteen attributes for success of graduated bachelor's degreed engineers, but did not categorize [technical versus non-technical knowledge and skills] nor statistically compare the student and industry groups. Further, their research did not discriminate on the basis of the student's status, that is graduate or under-graduate. Chelst, Falkenburg, and Nagle (1998) report on an industry-based engineering management master's program for the working engineer. Questions they addressed during program build-up phase were:

- "How can and educational experience be designed to "build the bridge" between technology and management?
- How do we adapt our curricula to focus on customer-driven needs…,?
- How can universities and employers work together…,?" (page 289)

From a stakeholder team limited to faculty at one institution and representatives of one manufacturer, they concluded that there were four primary goals in an engineering management program:

- "Develop skills to manage technology and technology change.
- Increase competency in a field of technical expertise.
- Develop systematic and analytic framework to support decision making.
- Develop business and human resources skills.
- Apply learning to problems of a product development and manufacturing enterprise" (page 290).

Gorman, et.al. (2001) report on their experience as participants in the Boeing *A. D. Welliver Summer Fellowship Program* and state that Boeing promotes an engineering education experience that counters the status quo with the "4Cs", which are collaboration, continuous learning, communication, and cost awareness. Their research also included a rich base of literature that cites the research completed by

McMasters and Matsch (1996) "…argu[ing] that engineers need a multi-disciplinary, systems perspective; they need to be flexible, able to think both creatively and critically, and possess the curiosity that promotes life-long learning" (page 144). Other research is cited, which reaches similar conclusions. Gorman, et. al. (2001) conclude from their summer fellowship, cognizance of Boeing's philosophy, and literature review that curricular improvements must be built on the following: a good grasp of technical fundamentals; a good understanding of design and manufacturing; good communication skills; an interest in life-long learning; and a profound understanding of teamwork" (page 145).

Todd, et.al (2001, p. 401) report on the importance of manufacturing and educating students for careers in manufacturing. They discuss the results of a Society of Automobile Engineers (SAE) self-reported, written survey completed in 1998 at which the following question was asked: "What are the most important technical or other challenges that new engineers face[?]". They argue that the most important are the following characteristics:

- "Working collaboratively,
- Systems engineering,
- Design for manufacturing,
- Dealing with change,
- Lean manufacturing, [and]
- Understanding manufacturing processes" (page 401)

One other very provocative finding that Todd, et.al (2001) report is a "Venn" diagrammed comparison of engineering knowledge and skills between industrial, manufacturing, and mechanical disciplines. A tri-discipline Venn convergence is found in the knowledge and skills of the *sciences, business, mathematics, humanities,* and *design*. Todd, et.al (2001) conclude by arguing for the importance of a review of the educational content in traditional engineering programs for the purpose of meeting the challenges suggested by the SAE survey. However, as in other studies reported in this section, they did not segment their student stakeholder population and there is no way to know how the results would differ for a graduate-level candidate.

2.5 Institutional Review

A requirement for periodic extra-institutional accreditation motivates an individual higher education entity to employ "intermediate means", self-studies, to assess the condition of its academic delivery process (Dill, Massy, et al., 1996).

Organized and entitled under various terms, such as "process improvement teams", agents of the organization develop and empower formally chartered, *ad hoc*, volunteer, appointee, and committee structures to validate, verify and execute the institution's goals and to recommend the means to assess its current status. During the "teams" activities and after their analysis phase term is concluded, recognized gaps between academic reality and institutional requirements may result in recommendations for "fixes" in its delivery process (Carey, 1998).

The outcome variance of these intermediate assessments could motivate the agents to amend the current review scheme along a spectrum of "improvement" activities (Carey, 1998). For example, the current state of the academic delivery system may suggest initiating a perpetual review process. An alternative to continuous review may be routine, periodic assessments, i.e., chronological analyses. Events-driven assessments could also be initiated. Finally, a combination of assessment review alternatives is possible. Similarly, the institution's goals may require change along a spectrum from "no change recommended" to, as Carey (1998) suggests, "complete substitution".

The ultimate choice of analysis systems – team structure and process - and limits to be selected for institutional assessment may also depend upon stimuli external to the "improvement team" – agents, stakeholders, technological change and so on. The choice may also depend on the degree of standardization in the improvement team. While the process of making decisions is improved when the system for making improvement choices is standardized, the process for systems choice can vary from individual to individual, institution to institution.

Assessment schema may resemble the outline of a structured award-type review like the Oklahoma State Quality Award Foundation (OQAF), the Rochester Institute of Technology (RIT) /*USA Today* Quality Cup, and the Malcolm Baldrige National Quality Award.

2.6 Baldrige National Quality Award and Higher Education

The concept of "total quality management" has been employed in a variety of applications across a number of college campuses (Carey, 1998). Academicians and administrators have suggested the implementation of a standard or reference criterion for self-administered improvement. One assessment reference is the "Baldrige National Quality Award Education Criteria for Performance Excellence" (Baldrige National Quality Program, 2001).

The "Baldrige National Quality Award Education Criteria for Performance Excellence" (BNQA) outlines a methodology for assessing an educational institution's establishment of an "Approach", "Delivery", and "Results" driven process for assessing relationships between the institution's core values and the processes' core values (Baldrige National Quality Program, 2001).

While the BNQA, the OQAF, RIT/USA Today Quality Cup, and other state-level quality processes have established procedures for assessing excellence in higher education, the academic delivery of higher education may be changing in anticipation of, or as a result of, competitive models of education and training made possible by electronic technologies (Bourne, Brodersen, et al., 1996).

The organization, therefore, requires a coherent methodology to develop, execute, and control strategies to meet stakeholder needs as they may be realized in forms of student experience with electronic delivery of engineering education.

2.7 Quality Review: An Example

"Listening to students to find out what was wrong with the system" is the catalyst which provoked a three year effort by Belmont University to successfully embark upon their quality improvement process, which eventually led to winning the inaugural *RIT / "USA Today" Quality Cup Award* for an institution of higher education (Hillenmeyer, 1996). Belmont University placed the student "customer" in the lead role as the entity for which the University must determine as being placed ahead of other parties peripheral to the education transformation process. The University then proceeded to develop and execute an improvement process balanced across departmental activities, while focusing on student satisfaction as being central to the effort, seeking to improve stakeholder value.

2.8 Stakeholder Value

A key to understanding stakeholder value is recognizing that a definition of *value* is uniquely defined and dependent: Each stakeholder has its own set of criteria to determine how well the [organization] is performing…[T]hese criteria typically deal with the direct and indirect impact of [organizational] activities on stakeholder interests (Wheelen & Hunger, 1998). This is later demonstrated [Chapter 5] by the similarities and differences in the "value" that this research project's participant groups placed upon a common set of characteristics for engineering students.

2.9 Stakeholder

Considerable literature exists to classify the "stakeholder". For the present research, key studies generically classifying the stakeholder are those by Williams (1995), Cegles (1998), Bebko (1998), Jones (1998), Xue (1998) and Barrios (1999). William establishes this set of people {parents, students, businesses, education, organizations, community residents, and service producers}. Cegles (1998) lists the names and titles of the set, but does not provide an explicit classification. Bebko (1998) similarly classifies the set as did Williams. Jones (1998) generally defines the stakeholder as "the customer of higher education." Xue (1998) says that it is "…hard to define [the stakeholder] for higher education." Barrios (1999) researches the stakeholder set and concludes with this population {industry, society, technical societies, ABET, and the family}.

"To be sure, no corporation can sustain itself without appropriate attention to all those who hold a stake in its performance: customers certainly, but also suppliers, creditors, neighbors, society in general and, of course, those most directly affected - employees" (Posner, 1992). While this definition of the stakeholder population could appear to be so inclusive as to be unworkable from the standpoint of simultaneously and equally meeting each constituent's needs, a better definition of the "set" may stem from the firm's *statement of operations*: "source stakeholders" - financial community and customers; "investing stakeholders" - investment community and stockholders; and "operating stakeholders" - employees and suppliers (Wheelen & Hunger, 1998). While taking a global perspective, the *public*, a *company's neighbors*, and the *"social good"* cannot be excluded from the universe of stakeholders. However, for purposes of this research, they are excluded, because appropriate measures of their distinctive concept of value are better understood from the perspective of the social sciences, which lay beyond the scope of this research project. Instead, the stakeholders tested are limited as discussed in Chapter 4.1 "Assumptions and Limitations."

2.10 Quality in Higher Education

A recent survey of engineering students at the School of Engineering, Auburn University revealed several important conclusions perhaps adding to the bias in interpreting any data resulting from a study of improvement efforts within any university that could be seen as an interrelated system of processes (Benefield, Trentham, et al., 1997). Benefield, Trentham, et. al. (1997) concluded the following points: first, student satisfaction and perceptions may be a function of class and major ; second, (Sounderajan, 2002) unspecified differences between various student populations and faculty may provoke unintended, opposite affects given identical change efforts; third, technical background may significantly influence perceptions in terms of satisfaction; fourth, (Richards & Mehreban, 1995) students perceive education within the context of passing licensure examinations - faculty place this attribute much lower in overall importance; and fifth, attitudinal surveys may be conducted at a macro level relative to the department and the results remain valid for planning departmental changes.

An earlier survey conducted within the City School District of Sacramento, California revealed a variety of entities operating to influence change efforts (Duarte & Coleman, 1988). The authors suggested that two distinctly different processes are simultaneously in operation: pedagogy (teaching and learning) and support functions (staff, plant, equipment, etc.). They concluded that quality change efforts could be successfully used when accompanied by "buy in" from stakeholders. Richards and Mehraban (1995) concluded that many institutions of higher education have pioneered TQM efforts; however, their research concluded that no criteria have been developed to assess the effectiveness of TQM programs. Their study developed a set of comprehensive criteria. Welch (1995) studied quality change efforts within the curricular design of opera education and concluded that the system of administrative, executive, and primary support jointly share in meeting the needs of the "direct customer" - the student participant.

While the topic of quality management (QM) has generated significant practitioner interest since the early 1980s (Juran 1981), QM has only emerged as an area of serious scholarly inquiry since the mid-

1980s. As Bourne, Brodersen, et. al. (1996) assert, "The need for more cost-effective and relevant engineering education is upon us."

Given the preceding studies, it may be concluded, that significant up-front effort should be made to invite a variety of stakeholders in planning quality improvement processes.

2.11 New Educational Forms

The Western Governors University, University of Phoenix, Athena University, Global Network Academy, National Universities Degree Consortium, National Technical University, and others characterize the new form of distance learning, virtual campus education on demand for the twenty-first century. Whereas higher education traditionally provided a "just-in-case" service, the new student demands a "just-in-time" system to meet his or her needs whenever, wherever they can fit the educational transformative process within their schedules. Along the way to the new model, the advent of "universal access" has not, however, witnessed a significant change in traditional higher education enrollments as a whole. Indeed, Raschke (1996) concludes that the "electronic university" will advance the goals of the "traditional university" better than traditional higher education and in ways that have nothing to do with cost or efficiency. In fact, more students of a demographic diversity never seen before are enrolled in for-credit courses provided by the traditional models, by on-line providers, and corporate systems (for example, Motorola University), at a rate that provokes all providers to take time to reflect upon the economics of future higher education.

2.12 Changes in Higher Education

The Boyer Commission (1998) concluded a six-month study in which the conditions in American higher education within the Nation's 3,500 research-based institutions were analyzed and recommendations were reported in the form of goals that schools should consider as shown in Table 2.2:

Table 2.2 Boyer Commission (1998) Goals for Higher Education

Build on the freshman foundation	Educate graduate students as apprentice teachers
Change faculty reward systems	Link communication skills and course work
Construct an inquiry-based freshman year	Make research-based learning the standard
Culminate with a capstone experience	Remove barriers to interdisciplinary education
Cultivate a sense of community	Use information technology creatively

While the Boyer Commission Report (1998) avoids content discussions (the implication is that accreditation entities, such as ABET Engineering Criteria 2002-2003 provide specific recommendations) and the common body of knowledge covered in "general education", it urges debate about the nature of education to produce widespread and sweeping reform (ABET, 2002).

The Boyer Commission Report (1998) details twenty separate, on-going initiatives resident in model institutions, which exemplify methodologies to meet those challenges noted in the report (listed above). A selected sample of the twenty initiatives appears as follows in Table 2.3:

Table 2.3 Summary of the Boyer Commission's Report (1998) Findings

Institution	**Educational Initiative**
Massachusetts Institute of Technology	Undergraduate Research Opportunities
Rensselaer Polytechnic Institute	Studio Format for Introductory Sciences
University of Delaware	Problem-based Learning
SUNY, Stony Brook	Undergraduate Research
Harvard University	Peer Instruction
University of Chicago	College Research Opportunities Program
Duke University	Block Scheduling
University of Utah	Liberal Education Acceleration Program
Stanford University	Sophomore Dialogues and Seminars
Princeton	Junior Independent Work and Senior Thesis
University of Maryland	"World Courses"

2.13 Changes in Learning Styles and Research Approaches

The pedagogical implications of a technologically enhanced, web-based learning system are to prompt superior results in the current "constructivist focused theory" of learning. Specifically, the student will experience:

- Active learning: student-centered, non-linear exploration of websites
- Individualization: what works best for the individual student versus a class of students
- Cooperative learning: peer motivation, involvement, negotiation, team-building
- Critical thinking: improved access to primary resources inviting critical comparisons
- Contextual learning: improved access to specific, context-focused websites
- Learning-to-learn: learning how to acquire information relevant to a wider variety of academic courses, professional and personal lives.

Jackson, Gordon, & Chisholm (1996) report the results of evaluating the effects of an innovative methodology of involving multi-disciplinary teams of students from various engineering schools at Queen's University. His observation-based research concludes that cooperative learning in a non-traditional and topical means, such as multi-disciplinary teamwork and problem-based learning is superior to classroom-based programs in producing graduates prepared for professional careers. Other research using qualitative survey designs explored the differences between freshman students' thinking concerning science, technology, and society. The Altman & Nair (1996) research revealed no significant difference between engineering and non-engineering students.

Houshmand, Papadakis, McDonough, Fowler, & Markle (1996) explored the use of the plan-do-study-act (PDSA) model to improve the quality of instruction. The study employed self-reported student questionnaires to judge the change in instructional content from the TQM intervention. The researchers report the efficacy of TQM methodologies like PDSA. Stedinger (1996) examined the effects of TQM in the classroom and reported that by adopting a customer-focus and establishing a dialogue with the students in the course that it was clear that lectures, notes, handouts, homework, and examinations could be improved. He employed a questionnaire instrument. Other researchers using TQM techniques to improve instructional delivery and course content are Diller (1994) and Litwhiler and Kiemele (1994).

Clearly, the most significant study was that reported by Bourne, Brodersen, et al. (1996), which described a model for implementing on-line learning in engineering education. They discussed the relationships between traditional learning strategies and network-enabled engineering education. Based on asynchronous learning networks, the model uses World Wide Web implementation strategies and presents an implementation model course developed for on-line presentation and evaluation.

2.14 Education and Networks

Gaede (1995) reports that the primary implication of network growth and digital access (libraries) is to provide multi-formatted, "anyplace", and "anytime" information. While the implications of this access are not yet fully understood, Gaede (1995) concludes, the availability of information provokes access to "education" on demand.

Many definitions may be ascribed to the "network" metaphor. In the present context, networks are considered synonymous with electronic communities: interconnected processes of information dissemination, storage and retrieval on demand by teacher and student.

Changes in Learning. "Learning on demand" and asynchronous learning networks (ALN) have become inseparable and, using an old metaphor, there may be difficulty classifying either term as the "chicken" or the "egg." ALN courses may be delivered through a variety of media to include on-line classes and are today's version of the correspondence course model pioneered in the early 1800s. The change offered through contemporary ALNs is virtually unlimited collaborative instructor-learner interaction. To support a common frame for ALN comparisons, Mayadas (1997) proposes "Five Pillars of ALNs" shown in Table 2.4:

Table 2.4 Mayadas' (1997) Five Pillars of Alternative Learning Networks

Pillar 1	Increased accessibility
Pillar 2	Learning effectiveness
Pillar 3	Faculty satisfaction
Pillar 4	Student satisfaction
Pillar 5	Cost-effectiveness

These points suggest that to demonstrate increased efficiency and effectiveness from the new models of learning and teaching in the networked age, it is necessary to show significant changes in accessibility, learning, faculty satisfaction, student satisfaction, and educational costs. Further, it may also be necessary to show the effects of varying ALN presentations or recommending this point as a follow-on study, since the effectiveness of a change in either teaching styles or learning environments would appear to be conditioned upon the manner in which either component is realized.

The United States Distance Learning Association released its summary report, "A Review of the Literature: Interactive Video Teletraining in Distance Learning Courses" (Payne, 1998). In his report, which was based upon 800 published and unpublished studies conducted from 1994 to 1998, Payne (1998) concluded the following: first, students will learn at least as much as they would in traditional [lecture] classes; second, it is not likely that students will consistently learn more than they would in traditional classes; and third, decision makers should use factors other than increases in learner achievement to justify using the technology, such as reduced costs, increase training opportunities, and standardized message delivery.

The evolutionary changes in engineering higher education delivery as a function of technology adoption [by the departments] are important to understand as a metaphor for change in the industrial education process, which are far less studied from an external audit source unless the external organizations have had an MBNQA review. This may result in an appreciation for the needs of industry in regards to the selectivity in the type/characteristics of the candidate they might consider.

2.15 Dimensions of Technology and Quality

The manufacturing and professional services stakeholders have specific judgments about the relative importance of technology and quality education desired in their engineering employees. The definitions of technology and quality used in this research are based upon the premise, which states that a technology will be adopted when the forces for its adoption outweigh those against its adoption (Hoff, 1997). Further, the relationship between their perceived notions of the implications of technology and its relationship to the type and educational qualifications of the person hired is unknown and may be an area for future research. Indeed, as Tavana, Kennedy and Joglekar (1996) conclude, "...the specific characteristics of the technical qualifications of the individual are very situationally dependent and require successive judgments about the taxonomy of such characteristics". The types of available products and services represented in the manufacturing and service industries present a daunting challenge for a synthesis of the specific technology and quality characteristics broadly applicable to each manufacturer provider.

2.16 The "New" Organizational Environmental Dimensions of the Industrial Engineer

Todd, Sorenson, et. al. (1993) suggests that the organizational form tends to motivate organizations to understand the *mechanism* for rapid employment and effective development of the talents and resources of the industrial engineer. The mechanism is *motivation*. Decentralized operations, INTERNET world-wide webbed communications, out-sourcing, technical entrepreneurs, and infinitely flat organizations are only a few of the terms that may used to scope the motivation opportunities and challenges for management and employee interaction in contemporary companies (Michels, 1996).

Early forms of virtual enterprises have been a part of commercial and federal government operations as project teams and military organizations. Dispersed operators, self-organized, accessible to information sources and to networks of operators and acting in accordance with a grand plan and individual tactical ingenuity have been an evolutionary element of military operations. Information technologies (IT) have expanded the definition of these early dispersed systems to include organizations to the level of an "individual foot soldier and the project engineer" who are connected to a larger organizational network (Wheelen & Hunger, 1998).

The evolution of the traditionally understood line and staff model organization from a "bricks and mortar" construct to a fluid, rapidly changing, and electronically virtual system of operators may require a new way to develop the potential and desire for the industrial engineer to produce in an environment of virtual management, change, and control. The organization's climate may be difficult to comprehend [for management and employee] as "virtual-commercial" firms electronically web the industrial engineer into production and functional staffs and production support groups, such as: operations management, project membership, planning, strategy development activities, and financial planning and control (Lai, Wong, et al., 2002) Managing the motivation process to encourage continuous, self-initiated creative processes is one challenge, and the other being the impact of virtual management upon the employee.

This section 2.16, then, reports on a cross-disciplinary study conducted by the author while enrolled as a graduate student in courses IEM 5413, "Theory of Systems Organization I" and MGMT 6313, "Advanced Organizational Behavior." The focus of the study was simply to gain an understanding of the thinking and impressions concerning the motivation of the industrial engineer in a rapidly changing organizational system.

2.16.1 Organizational Evolution

Many terms are used to define the current "re-engineering" phenomenon. Taking a structural and business process perspective, decentralization, *telecommuting, webbing, outsourcing,* and *technical intraprepeurs* and *entrepreneurs* may be several key terms. Similarly, from the information media perspective, *chief information officer (CIO), infopartnering, chief information and technology officer (CITO), information "conflict,"* [Department of Defense perspective], and *cyber-technology* are terms frequently used in INTERNET communications. While this study is not concerned with covering the "phrase of the month," business and management process analyses in "re-engineering" suggest a need for a broad view across the commercial enterprise that merges process change in the physical, human relations, commercial, and information forums. "Re-engineering will require paying attention not only to the issues of process, but also to the fundamental issues of management itself, how we think what we do..." (Champy, 1992 as reported in INTERNET, 1995).

Thomas Stewart says, "... [the] re-engineered company can be characterized as a loss of middle manager staircase [to the top] relations, redrawn boundaries that are tight around core competencies, but loose around outsourcers, and [significant] project-based work" (Stewart, 1995). Michael Strangelove continues the discussion in an INTERNET interview, "The 'new company' is seen as a strategy maker, a resource provider, populated with project managers directing talent centers of industrial engineer, who spend their productive time on project teams" (Strangelove, 1994). Ford Motor Company's "Ford 2000" is a philosophy of global interconnectivity to develop an electronically webbed, seamless project-based management process of technical professional core teams and individuals (Virtual Organization 1994). These commentators and the example of Ford appear to be saying that business, management, process, employees, markets, and the very concept of the "job" should be developed anew.

2.16.2 Human Relations Evolution

Employees have been affected by the electronic connectivity phenomena whether or not the connectivity was a voluntary and/or involuntary decision. Telecommuting, project dispersion, and Total Quality Management are terms frequently used to scope the range of the personal interrelationships. Rather than offer a socio-technical history of mankind and technology in this study, an observation that summarizes interviews conducted via INTERNET suggests that "webbed" employees have concerns beyond the technical:

> "I read a thread in the forum today a statement about people becoming so engrossed in the cyber world, that they are losing the skills necessary to facilitate their function in the 'real world.' For one solid year, my life was going to work in a basically isolated area of Western Canada where a lot of interaction wasn't necessary...coming home to my computer...going to bed at 3:00 a.m. and starting all over again. When I took a new job, my manager commented upon my lack of interpersonal communication skills. While my written skills had tremendously improved, my speaking skills had tremendously deteriorated. I eventually built them up again. However, we installed e-mail in the office, and my skills went down the drain again. I wonder about the effects upon students who become practitioners who will require interpersonal skills, such as physicians!" (Franks, 1995)

These comments support the need to address engineering students functioning as graduates in an organization characterized by out-of-sight relationships – the virtual organization.

2.16.3 Engineering Skills Development

Rugarcia, et. al. (2000) categorized skills needed by the engineer in the 21st century: lifetime learning; problem solving, creative thinking, critical thinking; interpersonal and teamwork; communication; self-assessment; and change-management. deOliveira, Borges, and Naveiro (1998, p. 198) argued that the engineer will require an education process that '...presupposes the learning/teaching process as a social process, that stimulates the student to think and work taking into account all of the aspects regarding the citizenship and not only the acquisition of technical/scientific knowledge.

2.16.4 The Industrial Engineer in the Organization

The challenge of the industrial engineer in the virtual organization was studied from the available published literature. The author conducted personal interviews with professionals in a variety of decentralized commercial and federal government operations as a requisite for a graduate-level industrial engineering course that was completed in the fall 1994. The focus on decentralized was important so as to model organizational interconnections beyond the "bricks and mortar" (Martin, 1990). Therefore, to better understand the industrial engineer in the virtual organization research proceeded along the path of longitudinal reviews that investigated the organizational evolution during the past two decades or those that prescribed a way of looking at the electronically interconnectivity motivation phenomena. To restate the introduction to section 2.16 of the Literature Review,

> "This section 2.16, then, reports on a cross-disciplinary study conducted by the author while enrolled as a graduate student in courses IEM 5413, "Theory of Systems Organization I" and MGMT 6313, "Advanced Organizational Behavior." The focus of the study was simply to gain an understanding of the thinking and impressions concerning the motivation of the industrial engineer in a rapidly changing organizational system."

Personal Interviews. Between 1994 and 1995, extensive interviews were conducted in person, by telephone, or by INTERNET [CompuServe's, Industry Week, "Virtual Enterprise Forum" chat room, and "Info CANADA" chat room] with a wide range of industrial engineering managers and technical/engineering business owners. While the use of the *Virtual Enterprise Forum* may appear to be self-evident, the *Info Canada Forum* resource may not be so clearly understood. To explain, from the author's personal experience as a military advisor to the Canadian Air Force, telecommunications are a vital information link for Canada.

From his home office work station connected on-line to the INTERNET, the author sought to simulate the "problem" of self-reported information via electronic means, as much as possible. Initially, he asked each respondent the questions appearing in Appendix B. When asked, each respondent then volunteered to pursue additional data collection. He asked each to query their organizations (as delimited by the group, team, and business they headed) to broaden the input. The author understood that some confounding of the results would occur due to fact that they, as a partial observer would be asking the questions. However, statistical analyses were never the intended result. Rather, a simulated virtual environment was sought in order to better understand the engineer in a virtual organization. Therefore, bias was an understood consequence. The author further intended to ascertain a summary of opinions that could serve to point the way toward future literature search development efforts into the study question. The total number of respondents was self-reported as 127. While a formal, statistically rigorous, unbiased interview instrument was not developed, Leedy's text served to develop a broad outline and detailed questions (Leedy, 1993). Reasons for the lack of rigorous pre-survey design was that the author had developed a personal relationship with the respondents over many years and the doctoral dissertation proposal was in its early stages.

Summary of Interviews. Each respondent had begun their career in a similar fashion, typical of the engineer that is hired by a large multi-national Fortune 500 corporation and assigned for the first few years to a production facility. Later, progressing to management levels within general business departments (versus strict progression within engineering disciplines), they self-reported being selected for situations best characterized as self-organizing, electronically interconnected project teams. Synthesizing their opinions, a general view of the virtual management system of motivation and the implications for the engineer began to emerge as listed in Table 2.5.

Table 2.5 Summary of Personal Interviews

"Dual ladder" career progression	Organization for creativity
Classifying the industrial engineer	Rewards
Individual needs	Rules and regulations
Interpersonal communications	Satisfaction and motivation
Managing creative intellect	Self-managing teams
Man-machine	Virtual presence

Manz (1992) developed two concepts important to understanding *self-leading* teams: one, individual characteristics necessary to operate within a team are autonomy, cognitive conceptual skills, self-directedness, and self-motivation; and two, within the work environment are the nature of the task (creative, routine, ambiguousness); the type of the technology (process, product, and pooled interdependence), and the nature of the environment (Manz, 1992). Martin (1990) stressed the importance of goal's congruence with organizational objectives. In fact, Posner (1992) stated that the alignment of personal and organizational objectives was directly linked to positive work attitudes. Salvendy & Karwowski (1994) commented about the *satisfaction and motivation* system by expanding the Hackman & Oldham (1976) model to conclude that satisfaction is an antecedent of motivation, given: control over work processes; participation in decision making; ability to use training, education, and skills in doing a task; feedback; and the ability to fulfill a meaningful and significant task. Cohen & Ledford (1994) expanded upon the Manz (1992) construct and commented upon the role of technology, process, and their management implications. In their study, *self-leading* teams fit well with the new technologies which permit electronic allocation of work assignments from a central dispatch office; they work well in situations that permitted a high level of interdependence and a high level of employee information processing; they need situational structuring; and, interestingly enough, do not increase all types of effectiveness for all types of work. Several researchers provided further comment upon the needs of individuals within *self-leading* teams (Quinn, 1992), in studying the intelligent enterprise, said that innovative "adhocracies," advertising agencies, research groups, consultancies, and real estate syndicates are forms of future open systems in which the structure fits the situation, the task forms the organization (Von Glinow & Mohrman, 1990). Quinn (1992) continued, "New technologies have made it possible to disaggregate, delegate, and manage work at much more decentralized and refined levels within and across enterprises" (Quinn, 1992, p. xv). In fact, the researcher concluded that "outsourcing" is a key to success (Quinn, 1992, p. 380).

Managing creative intellect was a comment made by the respondents. Several researchers have studied this phenomenon Quinn (1992) called for "management to motivate the creative person" (Quinn, 1992, p. 109). Rubenstein (1989) studied 210 firms over a thirty year period of time. He concluded that management must effect idea flows and encourage creative sources (Rubenstein, 1989, p. 241). Juran (1989) devotes an entire chapter to the "problem" of implementing, directing, and sustaining (motivation) the singular most important organization change process in the past twenty-five years -- *quality*. Juran discusses the organizational obstacles to quality implementation: "unawareness, sub optimization, lack of priority, and culture" and says that "...communication, self-interest, and participation are management tools to deal with these obstacles" Joiner (1994) expands upon Dr. Juran's thesis and says that in order to develop a creatively innovative organizational climate, that the manager must be creative by encouraging employee questions and to "...communicate continuously to negate Newton's Third Law -- a body at rest tends to stay at rest". Martin provided an entire appendix to his book to cover the subject of managing creative intellect and said that creative processes are encouraged by seeing them as extensions of personality attributes (Martin, 1990). Personality attributes are indicators of personal creative ability and creativity requires the ability to think at a non-verbal level without the decline in the capacity for abstract thought and logical analysis. (Martin, 1990) Perhaps his most important discussion concerned Hudson's (1966) "Convergent/Divergent Tension" process for idea and solution process. From Hudson's study and his own, Martin (1990) structured a set of characteristics of the creative individual: high inner standards, breadth of interest, personal autonomy, dependable, interpersonal conflict avoiding, challenge of legitimate rules and constraints to enrich their perceptions and insights. Martin (1990) concluded by stating that creativity in one endeavor may be indicative of the potential for creativity in another. As the interview respondents said, "...finding the creative person is very hard, but once you have found them, you don't let them go." Von Glinow & Mohrman (1990) called for disciplined management structures that adapt to the situation and foster an environment to maintain the energy of creativity and innovation. Their research into "Silicon Valley" startups and innovative firms concluded that no [organizational] form fits every situation --" firm must be defined by its task structure, not its job descriptions". Kirp & Rice (1988) developed their system of conditions that foster creativity among "Silicon Valley" firms: diminished forms of organizational norms and forms that slow the pace of change. "As the shark has no bones, but cartilage, so too are distinct forms of organization to be discarded".

These comments lead to considering those researchers who have studied *organizing for creativity*. Quinn (1992) reviewed Apple Corporation's network and concluded that it's linkages of objectives to creativity throughout the system have fueled the energy of creativity. Salvendy (1994) linked the participation of employees, unions, and supervisors. Rather than a reactive improvised system, he observed a dynamic interrelationship in which work force strategies are coordinated with technology, task, environment, and the productive organization. In a recent Fortune article, Jacob (1995) said, "The ability to organize employees in innovation and flexible ways and the enthusiasm with which so many American companies have deployed self-managing teams are why United States industries are looking so competitive." Of significance, Rubenstein (1989) concluded his research in this area, "most all research concerning organizational structure and idea generation is dated." Further, his findings challenged the talk about stable, close-looped systems with the perceived need to be open to new forms of communication. Kay (1990) found that formal structure is necessary only to manage the creative processes versus the external business reporting requirements. He observed that the technology innovating company is characterized by the essence of its people in their capacity for change, their creativity, risk taking, and trust. Kay's (1990) conclusion, as that of Von Glinow & Mohrman (1990), was that rules and regulations are designed to maintain the structure and not the management of talent. "Rules and regulations get in the way of flexibility; the challenge of innovation demands creativity." Kay (1990) and Katz (1988) detailed the creative organization: open channels of communication; outside accessible/open systems; managers tolerating risk taking; autonomy; decentralization; and new idea generating.

Several respondents discussed the need for a "*dual ladder*" management system. In their opinion, "upper management" does not understand the industrial engineer. The published literature concludes with mixed findings. Most concluded that creative organizations should not design a system by which the career of the "traditional" manager follows one upward path, while the industrial engineer follows another path. Such systems require extensive management and structure that instill organizational inertia, costly and time consuming to change (Katz, 1988, Bridges, 1994; Martin, 1990; Von Glinow & Mohrman, 1990).

In reviewing the *individual needs* for the rewards of compensation and career promotion, a wealth of research is available. The sources researched for this study follow the perspective that the industrial engineer is concerned with the congruence of individual goals and those of the organization. Further, a system of fair compensation and promotion are needed by the industrial engineer. However, it appears that of greater concern [to the industrial engineer] is the need for *challenge* of the problem and for the innovation of a new solution (Rubenstein, 1989). Katz (1988, p. 37) cited a study (Pelz, in publication) in which 1300 scientists and engineers were studied concerning creative tension and organizational environment. Pelz concluded that the *tension of challenge* lead to individual creative effort.

The impact of "man and machine" was a potential source of concern among the respondents. Much has been written about the concept of "social cybernetics." This study sought published research into the virtual enterprise and the man-machine concept. Salvendy (1994) developed the research along the lines of interconnecting the dispersed individual with the computer integrated manufacturing system. His studies extended the dispersion points of automated cells to automated islands, continents and a world-wide web of interconnected individuals. He assessed the impact upon labor and management and concluded that information automation will affect the way industrials engineer work and live; integration of ideas must be two-way and technology decentralized to effect connectivity.

The *virtual presence* of future businesses was an issue every respondent discussed. All felt that it will be vital to understand the concept and to effectively manage it for companies numbering one member to thousands of members. In 1997, the federal Department of Defense was well on-the-road towards a 100% electronic commerce. Being a member of the Oklahoma task force designing the system by which Oklahoma companies will be involved in the system -- CATT/CALS, it has been a difficult process to describe and encourage participation in virtual commerce. Several scholars have approached an understanding of the process toward this need. Salvendy (1994) called it "tele-presence". Bernier (1995) said that it will link creative elements in a world-wide system of capabilities and production. Ohmae (1989) concluded that involving the world in "Borderless" markets will demand instantaneous interconnectivity of strategy and organization to meet a diverse need. Ford 2000 is a corporate program for the creation of a virtual corporation of dispersed resources to meet the needs of dispersed niches globally. Benjamin (1989) was more emphatic than Ohmae (1989) and said that the role of the firm is outmoded.

What is needed are "markets, not firms". Gilder (1991) called the virtual enterprise a decentralized information "heterarchy". Aktouf (1992), commenting upon the need to rethink the role of management and organization, saw human involvement as essential elements for movement beyond strict mechanistic forms of enterprise.

Each respondent inferred that the *job* is dead. In the future, task performers will populate task teams to complete projects. In a Fortune article, Bridges (1994) talked about the "End of the Job." His research uncovered these conclusions: the hierarchy will implode, people will report to themselves; projects and task forces will accomplish work, jobs and job descriptions will be eliminated; the post-job organization will be characterized as flat, vendor-oriented, flexible, and will employ "packages of capability"; careers need to be re-conceptualized and new compensation and training mechanisms developed ; managers will become providers of access [to information]; and that task *completers* will need to show desire, ability, and assets. Bridges characterizes the employee as operating in this environment as though motivation is assured through needs for compensation and information. While this viewpoint differs little from that reached by other respondents, the aggregation of opinion, perhaps, lends weight to the conclusion that motivation of the engineer in the virtual enterprise (from the organization's perspective) remains akin to the system in the traditional firm.

Motivation of the Industrial Engineer within the virtual enterprise was the focus of the anecdotal study. The respondents did not feel that they treated their employees any differently than when people were primarily within line-of-sight. The literature search was unrevealing to dispute the Steers & Porter (1991) comments concerning the lack of an integration model of individual, job, and environment. Katz (1988) concluded that motivation is intrinsic and all that the industrial engineer manager can do is create the conditions and environment conducive to motivation. The individual, in Katz's model, is to take advantage of this environment and the conditions and to respond in a manner to promote his personal as well as organizational goals. He goes on to say that neither content nor process are appropriate to every person in every situation. The needs are career advancement, pay, and challenging work. Of significance, he says that the industrial engineer will not be motivated by such extrinsic things as films, memos, and outside consultants. Some of the lack of finding may have to do with "prejudices" that the industrial engineer does not "like" to manage. Therefore, observing what makes them act may be more of a consequence of "throwing problems over the wall" for them to solve versus having the industrial engineer emerge from the darkness to manage the problem from the beginning. Katz (1988) cited an earlier study (Shepard, 1958), which concluded that the engineer cannot manage; therefore, Shepard (1958) would have the company optimize the structure of organization and treat engineers as machines to process solutions. Kay (1990) developed an entirely opposite approach and concluded that the industrial engineer cannot wait to manage. He said that they have the ability and talent to manage the needs of the virtual organization. However, even the Kay (1990) model does little to shed light on the real issue of motivational unification of individual, task, and environment.

As previously discussed, Steers & Porter (1991) framed a model to characterize a unification of the intrinsic and extrinsic approaches to motivation. Their's is a component summary of individual, job and organizational work environments. While the behavioral and consequential elements may be observed, the difficulty in complete integration (of the elements) may lie in the "causes and effects" associated within each component.

The focus of the author's (1995) study was simply to gain an understanding of the thinking and impressions concerning the motivation of the industrial engineer in a rapidly changing organizational system. The notion of the organizational system was then broadened [by this author] to include the virtual enterprise. It would appear from both sources that the industrial engineer does not differ in motivational patterns from their non-technical brethren. However, the two organizational actors simultaneously face a new way of organizing talent and linking this resource to a decentralized productive system so as to fashion a commercial response to world-wide consuming markets.

The literature presented in this section suggests that a unified model of factors important in individual, job, and work environments is so highly variant as to make a one best approach as elusive as a one best fit for an organizational structure to fit every economic market (Lee, 1995). The Steers & Porter (1991) conclusion is sustained by a summary of anecdotal personal interviews.

In sum, respondents stated that strict job descriptions are unnecessary and delimiting, once the task accomplishing capability of the individual is electronically "captured" by the virtual corporation. That is, according to the respondents, "...find out who can do 'the task' and then use them in future projects." Not a simple endeavor, say the respondents, but very important to maintain flexibility, challenge, and independence for organizational actors. A primary difficulty is the form and timeliness of the information screens that the virtual organization places into the information stream. Maintenance requirements and appropriate selectivity are constantly changing due to the lack of information standards and protocols in the information universe. Finding the talented industrial engineer and characterizing the antecedents for their creative drive(s) in an electronic fashion is not easy (Lee, 1995).

Interfacing the dispersed technical profession directly with advanced manufacturing systems may require a holistic view of individual and business in which individual capability is not confused with company loyalty (Lee, 1995).

Companies may have to initiate the business of training their employees to be "outsourcers" -- providers of capability to more than one firm. This may appear to be heretical in the extreme and, at least, counter-productive. However, the rapidly changing and nearly infinitely responsive virtual enterprise will employ the talents of a network of providers. As Rubenstein (1989) calls them, "super designers".

Finally, companies will need to consider their humanity -- their human resources. Already, the tele-commuter is rebelling against the virtual office (Connelly, 1995). The politics of the office appears to be a motivating influence for a variety of responses. The virtual enterprise may or may not be as influencing as a system, from the dispersed individual's perspective. A new way of considering the individual from the manager's point of view seems inevitable.

In conclusion, the complexities of the graduate-level engineer's work environment and the demands of the employing organizations suggest the imperative for use of a decision tool that evaluates qualitative factors.

2.17 Methods for Evaluating and Measuring Stakeholder Judgments

Methods to model and analyze the "voice of the customer" include single attribute and multiple attribute analyses. Single attribute models include engineering economic analysis, "primitive" models, formal decision analysis, and utility theory. Multiple attribute analysis includes elementary models, quality function deployment, analytical hierarchy processes, principal components, and multicriteria models, such as multi-attribute utility theory, and multiple dimensional scaling.

2.17.1 Single Attribute Analysis

Among single attribute analysis models, a traditional method is engineering economic analysis, represented by net present value, payback period, benefit/cost ratio, and internal rate of return. These methods use cash flows, time, and interest rates. Since this research proposes to collect qualitative information not including cash flows, the economic analysis, single attribute model is not appropriate. However, the following is a brief discussion of each method.

So-called "primitive models" include those techniques, which do not use probability assessments and may be considered as inferior to multi-attribute utility theory (Tedesco, 1998). Naïve forecasting, Laplace criterion, the Maximax/maximin criterion are examples. They also primarily rely upon economic payoffs for comparative analyses.

Formal decision analysis includes the use of decision trees and chance nodes. However, the difficulty with using these models is similar to that of other candidates – the necessity for defining outcomes in economically comparative terms. Therefore, among single attribute models thus far discussed none would appear to allow for more than variables of economic interest to be comparatively analyzed. In this research, non-economic factors are to be assessed and, as a result, another approach is needed.

Single attribute utility theory allows for analytic treatment of more than the economic variable of interest. The value of the stakeholder for one outcome over another may be measured and compared on one scale for all variables. Utility is measured as an outcome on an ordered scale with an arbitrary "zero" reference analogous to a temperature scale. The problem with this scaling system is that successive probing using differing probabilities for "winning the lottery" will achieve results (Tedesco, 1998). As Professor Jonathan Bard concludes (in Tedesco), the construction, execution, and analysis of a utility function is "not easy" and poses considerable effort on the part of the surveyor to constantly coax the respondent (Bard, 1992; Tedesco, 1998).

Since the problem of the institutional decision maker is to develop engineering curricula sensitive to a set of multiple needs, which represent a wide variety of individual stakeholders, the use of a single attribute model is not used in this research.

2.17.2 Multiple Attribute Analysis

Among the multiple attribute models are the lexicographic ordering, conjunctive/disjunctive ordering, extended utility, additive utility, additive preference, weighted index, and priority theory tools. These techniques are briefly discussed, since the purpose of this research was to determine a method that evaluates a variety of alternatives for deciding upon engineering curricula.

Lexicographic ordering requires that all but the most important attribute of the decision to be eliminated. Because this process results in a single-attribute model, it suffers from the single attribute problems previously noted.

Conjunctive/disjunctive methods may be used to cull alternatives that fail to meet all (conjunctive) or at least one (disjunctive) of the criteria set as standards for the decision alternatives. As this research does not attempt to eliminate alternatives, but to measure their comparative weights, the conjunctive/disjunctive ordering method is not used.

Various utility methods may be used. Classified under the general heading, "multi-attribute utility theory" (MAUT), these are highly normative methods which suffer the same difficulty in execution as previously discussed under the single attribute tools. As a result, the MAUT models are not employed in this research.

Priority theory tools include the weighted index and analytical hierarchy process tools. Weighted index is generally discussed as the criterion that provides the best-weighted average of all the attributes of the problem. The problem with this tool is that the weighting scheme is left to the analyst. This presumes a clear set of preferences be established in advance of the collection of data from the respondents. Further, it also requires that the data be normalized, but is non-specific in regards to the normalizing constant. This means that the criteria may be normalized in regards to an average, the minimum or maximum of the values, or any other constant. This can result in arbitrary rankings of alternatives, a problem that this research intends to reduce.

The analytical hierarchy process is a more descriptive approach to multi-attribute decisions and appears to model the decision maker's ideal approach to structuring complex problems.

2.17.3 Analytical Hierarchy Process Modeling

Analytical hierarchy process (AHP) modeling has been used as a decision making approach in a large number of "hard" and "soft" engineering applications since the method was developed and published by Dr. Thomas L. Saaty (Drake, 1998). For example, Drake (1998) discusses the use of AHP in the selection of a hydraulic pump meeting competing conditions ["Hard" application]. Tavana, Kennedy, and Joglekar (1996) report on the use of AHP in the selection of technical manager candidates ["Soft"]. In his research, Saaty specifies the characteristics and advantages of AHP as a method for making choices from among competing alternative solutions, which relate to the present research. AHP models possess three principles particularly efficacious in this research: identity and decomposition; comparative judgments; and the synthesis of priorities.

First, AHP models are structured as a decomposition of a complex, multi-criteria problem into a hierarchy of manageable elements (Saaty, 1986; Saaty, 1988; Saaty, 2000; Saaty & Alexander, 1981; Saaty & Alexander, 1989; Saaty & Kearns, 1985; Saaty & Vargas, 1991; and Zakarian & Kusiak, 1999). The characteristic form of AHP is the hierarchy. For example, Figure 2.2 shows a three-level hierarchy representing the simplest Saaty model. Level 1 is the "focus" or "problem" to be solved by the alternative solutions. Level 2 is a set of characteristics of the problem. Level 3 (as well as levels below level 3) can be additional sub-characteristics, also known as children of the level immediately above – the parent (Saaty & Alexander 1981). Alternatively, level 3 (or the lowest hierarchical level) may also be used to depict the alternative solutions to the problem. Saaty discusses a "reasonable" number of levels for purposes of decision-makers as limited to five. In the present research, it is demonstrated that the student graduate of a graduate-level industrial engineering program (level 1) can be decomposed into a set of characteristics (level 2) and sub-characteristics (level 3), which reasonably model the possible judgments for stakeholders.

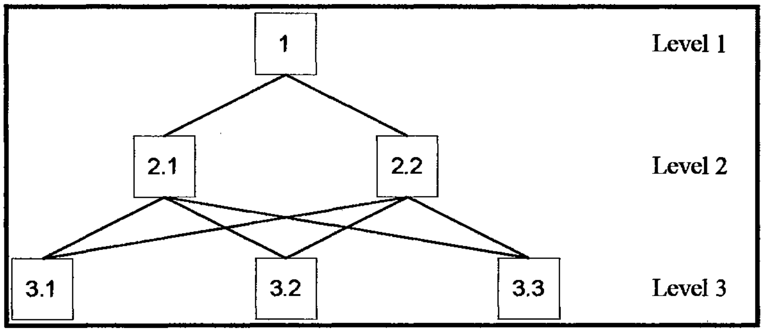


Figure 2.2 Generic Analytic Hierarchy Process Model

The second characteristic of the AHP methodology involves the judged comparative enumeration of a decision, since AHP assumes comparative measurement on a ratio scale. This notion is the heart of AHP, since it allows for the comparison of elements on the basis of relative intensity (as measured on a scale from "1" = "equal importance" to a ranking of "9" = "one alternative is absolutely more important that the other alternative"). This notion also allows for the comparative ranking, "judgment", for quantitative and qualitative aspects of the elements. For example, Table 2.6 tabularizes the priorities along a Saaty scale for two generic factors A and B and explains the "weights" given the comparisons between them. AHP can also be used to make absolute judgments by scoring lower level elements with respect to higher level elements. For example, if a decision maker were anticipating the selection of one automobile from among all the cars on the dealer's lot (Saaty, 1986).

Table 2.6 The Saaty (1986) Nine Point Scale of Priority Judgments

If factor "A" [factor "B"] is ... as (than) factor "B" [factor "A"], then assign the number... as the weight [strength of the priority], because ...

Factors A, B	Weight	Comparative Judgment
Equally important	1	Two factors contribute equally to the objective.
	2	
Weakly more important	3	Experience and judgment slightly favor one factor
	4	
Strongly more important	5	Experience and judgment strongly favor one factor
	6	
Very strongly more important	7	Experience and judgment very strongly favor one factor
	8	
Absolutely more important	9	Experience and judgment absolutely favor one factor

The reciprocal of the above "weights" are awarded when a factor is less important than the other factor. For example, if factor "A" is very strongly more important than factor "B", it would receive a weight of "7". Simultaneously, factor "B" would receive a weight of "1/7".

The third principle of the AHP is called the "Principle of Synthesis of Priorities" (Saaty, 1980). This principle states that relative priority weights can be calculated through the determination of the Eigen vector of the normalized reciprocal matrix. As such, a set of local priorities can be found that describe the importance of a lower level set of characteristics on the next higher level. In this manner, the relative weight of each characteristic is determined and the ranking of alternative solutions is possible [See Chapter 4, Section 4.7 for an example of AHP].

Beyond the contention (by the author) that the analytical hierarchy process is a more descriptive approach to multi-attribute decisions and appears to model the decision maker's ideal approach to structuring complex problems, two additional advantages of AHP over multi-attribute models are suggested.. These advantages are, first, its ability to measure the consistency of decision makers' judgments; and, second, AHP can address group judgments in addition to individual judgments. These two advantages support the current research project, where it was determined necessary to compare the individual judgments of stakeholders, respondents. In the research, the respondents are synthesized into homogenous "group" judgments for analysis and comparison between the respondent groups.

Consistency of judgments. Computing the consistency of judgments results in a dimensionless number (consistency ratio) that relates to "how consistent is the decision maker in their responses." A higher number means they are less consistent, while a lower number corresponds to more consistent judgments. The consistency ratio (CR) is found as follows:

$$CR = \frac{CI}{RI},$$

$$CI = \frac{\lambda - n}{n - 1},$$

Where: CI = Consistency Index of the matrix

λ = Eigen value (maximum) for the matrix

n = size of the matrix

RI = Random index of the matrix

A CR of 0.10 or less is acceptable; $0.10 \leq CR \leq 0.20$ is tolerable; and $0.20 \leq CR$ the decision maker should be queried about revising their judgments (Veerakool, 1988)

Other advantages to AHP are given in the literature (Saaty, 1986) as follows:

- Process repetition: The AHP enables people to refine their definition of a problem and to improve their judgment through repetition,
- Unity: The AHP provides a single easily understood, flexible model for a wide variety of unstructured problems,
- Judgment and consensus: The AHP does not rely on consensus, but synthesizes a representative outcome from diverse judgments,
- Tradeoffs: The AHP takes into consideration the relative priorities of factors in a system and enables people to select the best alternative,
- Measurement: The AHP provides a scale for measuring intangibles and a method for establishing priorities,
- Interdependence: The AHP can deal with the interdependence of elements in a system and does not insist on linear thinking, and

- Complexity: The AHP integrates deductive and systems approaches in solving complex problems.

Table 2.7 is an overview of the AHP process (Saaty & Kearns, 1985). The specific use of this algorithm is further demonstrated in Chapters 3 and 4.

Table 2.7 Summary of Saaty's (1985) Analytical Hierarchy Process

Step#	Task
1.	Define the problem and the desired solution.
2.	Structure the hierarchy as an overall management perspective, starting from the top, through (the) intermediate level(s), to the bottom level at which intervention is possible. This is accomplished by broadly defining sets of criteria that influence the problem. Inc
3.	Construct a set of pairwise comparison matrices for each of the lower level for each element in the level immediately above (See Table 2.6). There are $n(n-1)/2$ pairwise comparisons, "judgments", required to develop each matrix.
4.	Obtain all judgments required to develop the set of matrices called for in "step 3".
5.	Following the collection of all pairwise comparisons, obtain the priorities and test for consistency.
6.	Complete steps 3, 4, and 5 for all levels of the hierarchy.
7.	Synthesize the hierarchy to weight the vectors of priorities by the weights of the criteria.

The research literature is rich in the reach and depth arguing the use of the AHP model, because of its simplicity in modeling complex relationships. Of significant importance to this research project, (Zakarian & Kusiak, 1999; Calantone, Di Benedetto, & Schmidt, 1999; Chan, Chan, & Tang, 2000; Easley, Valacich, & Venkataramanan, 2000; Evered, 1984; Karapetrovic, 1998; Marose, 1982; and Armacost, Componation, Mullens, & Swart, 1994) approach individual judgments for application to qualitative problems. A group judgment case is addressed in the (Lai, Wong, & Cheung, 2002) research and discussed by Saaty (numerous).

2.17.3.1 Hierarchy of Academic Engineering Requirements

The literature is sparse that argues for the outcomes of a graduate engineering education drawn from the needs of manufacturing stakeholder in any hierarchical model. However, since the research anticipated use of a quantitative comparative weighting scheme with qualitative data and that the Saaty AHP model appeared to provide the necessary framework, an investigation of the Expert Choice homepage [http://www.expertchoice.com] reported approximately 1,450 studies using AHP (Expert Choice, 2002). However, the reported *engineering education* and the *engineering education assessment* literature are very limited in (un)published studies of the phenomena of stakeholder preferences for the education of the engineering graduate (Expert Choice, 2002). Bahurmoz (2003) reports that, "...only a few papers concern the application of AHP to decision making in education (Hope and Sharp 1998, Liberatore, et.al., 1992, Liberatore and Nydick 1997, Saaty 1996)." Previous research (Leepatanapan, 1997) argued for an AHP model of undergraduate engineering characteristic. However, this earlier research was limited to the Thai manufacturing sector.

The Leepatanapan (1997) research models the pair-wise judgments within and between the factors comprising the *customer requirements* and *engineering characteristics;* the alternatives available to the manufacturing and professional service company decision maker. Table 2.8 summarizes and simplifies the terms from that scholarly work (Leepatanapan, 1997). It shows the goal of developing engineering curricula at the undergraduate level as a hierarchy decomposed into comparative characteristics of the engineering curricula.

Table 2.8 Modified Hierarchy: Academic Engineering Requirements for Undergraduates

Level 0	Engineering Curricula	**Level 1 -**	Engineering Characteristics
			Interaction Capabilities
Level 2 -	**Engineering Characteristics**	**Level 2 -**	**Interaction Capabilities**
	Design for production		Teamwork
	Engineering materials		Communications
	Manufacturing processes		Information and PC literacy
	Manufacturing systems and automation		Liberal studies
	Manufacturing management		
	Scientific fundamentals		

In summary, there is literature reported on the use of the AHP in quantitative and qualitative decision-making. In the literature of engineering education, however, no previous research is found that specifically evaluates the graduate-level academic expectations of stakeholders.

2.18 Requirements for a Decision Method

The question, "What makes a good decision making tool?" was answered by Fahnri and Spatig (1990) when they proposed a set of criteria that all models should provide the decision maker. Table 2.9 summarizes their findings.

Table 2.9 Fahnri and Spatig (1990) Taxonomy of Decision Criteria

Speed of evaluation	Able to weight alternatives
Flexibility	Able to cope with multiple objectives
Able to structure the problem	Able to consider quantitative criteria
Appeals intuitively to the decision maker	Able to consider qualitative criteria
Able to eliminate inferior alternatives	Able to synthesize group decisions.
Able to rank order alternatives	Able to weight alternatives

Tedesco (1998) and others report that AHP performs better than other decision tools in many of the parameters Fahnri suggests. For this reason and for the conclusion reached by Bard (1992) concerning use of the complex MAUT tool, the author decided to use Saaty's AHP method in this research.

2.19 Summary

This chapter began with these premises:

- Higher education's engineering programs and their stakeholders' requirements should be aligned to provide graduate-level engineers linked to the requirements of internal and external stakeholders, and
- Previous research into a demand-pull methodology for engineering skills alignment at the graduate-level is unknown.

Therefore, the purpose of this chapter was to investigate the research problem from the perspective of the stakeholder, the higher educational environment, and the industrial engineering graduate student. Table 2.1, page 11 outlined the relevant sections covering these perspectives and Figure 2.1, page 12 provided a visual mapping of the chapter's sequence.

The environment of decision-makers in higher education is characterized by a complex set of internal and external forces stemming from stakeholders with an interest in the outcome of engineering programs. At the same time, researchers are arguing for a more collaborative engineering discipline, one more attuned to cross-disciplinary interaction. Students also have requirements, although research data are sparse.

Alignment of their respective requirements appears relevant from the literature reporting research into the needs of the stakeholders. Further, it is also concluded that research into a demand pull from the engineering consumer does not address the graduate student. Further, earlier research is not in agreement upon a measure for the term *alignment*.

As Saaty (1973) said,

> "Employers seeing to find the appropriate candidate for a job, depend on recommendations from such people as teachers, other persons, and employers. They all supply information regarding the ability, integrity, discretion, temperament, maturity, sense of values, initiative and diligence of the person concerned. It thus becomes difficult at times to distinguish between people on the basis of such recommendations ... scales do not seem to fit into models of the calculus and of equations." (Saaty, 1973)

The Industry-University-Government Roundtable for Enhancing Engineering Education (IUGREEE) (Lang, Cruse, et al., 1999) developed an industry-needs based survey of manufacturing firms, which resulted in categorically ranked criteria of the eleven ABET Category 3 outcomes. Lang, Cruse, et. al. (1999) concluded that the IUGREEE survey "...provides an example of what can be obtained from industry to better understand their outcomes expectations for entry level engineers". Puerzer & Rooney (2002) report on the results of a survey of graduates of engineering schools based on the eleven ABET EC2000 Category 3 outcomes. Their research was based upon surveys of engineering schools' alumni. The survey reported a need "...to develop a systems perspective on addressing the outcomes in a manner that is reflected in the engineering curricula" (Puerzer & Rooney, 2002). Anecdotal evidence from Sarin's internet-based survey revealed a wide variety of "...things that we can do to enhance abilities" [of the engineering student] to address the "soft six" ABET EC2000 [category 3] Outcomes (Sarin, 2002).

Chapter 3. Methodology

3.1 Introduction

This chapter presents the methodology to study the research objective and the sub-objectives. It begins by reintroducing the "Statement of the Problem", the "purpose of the Research" and the "Sub-objectives." Section 3.2 then discusses the research plan; the data to be secured for the research and their admissibility; the method selected for obtaining a consensus of opinion; and assessing comparative judgments.

Table 3.1 maps this chapter and is the methodology proposed to answer the research objectives. It is based upon a synthesis of various approaches to qualitative observational research (Leedy, 1993; Patton, 1980; and Fowler, 2002). In addition, Table 3.1 includes a column, "Saaty step(s)", to map the research methodology steps to the Saaty algorithm (See chapter 2, Table 2.7, which is repeated in this chapter, Table 3.2).

Table 3.1 Research Plan

Step	Description of the Step	Saaty step(s)*
1	Develop questions about the alignment of goals between the stakeholders.	1
2	Develop a survey research plan.	
3	Develop requirements for academia, employer, and student stakeholders.	
4	Develop an AHP hierarchy.	2
5	Develop a research instrument based upon the AHP hierarchy.	
6	Pretest the research instrument.	
7	Execute the survey research.	
8	Gather data from the survey instruments.	
9	Prepare the data for insertion into an Expert Choice© PC application.	3 & 4
10	Develop hypotheses about the alignment of goals between the stakeholders.	
11	Analyze each research instrument.	5, 6, & 7
12	Develop and execute statistical analyses.	
13	Draw and state conclusions	
*	(Refers to the steps in Saaty-based decision making. See Figure 3.2)	

To repeat the "Statement of the Problem", "Engineering programs and stakeholder needs must be aligned to provide graduate-level engineers academically prepared to meet the requirements of a variety of stakeholders. The objective of this research project is to

Determine a methodology or sequential approach for measuring the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers academically prepared to meet the requirements of selected stakeholders"

As discussed in Chapter 1, to complete the research project, the objective was stratified into these five sub-objectives:

3.1.1 Sub-objective 1

Develop a methodology to understand the needs of a stakeholder in the industrial engineering graduate student and to understand the process of obtaining a consensus of opinion about their needs.

3.1.2 Sub-objective 2

Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes. A demand-pull process should clearly understand the skills and knowledge requirements, the hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

3.1.3 Sub-objective 3

Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes. The demand-pull process should have the academicians understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationships among the requirements, and the weights [priorities] given these skills and knowledge.

3.1.4 Sub-objective 4

Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes. The demand-pull process should have the students understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions the demand-pull process should develop a unique set of hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

3.1.5 Sub-objective 5

Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.

3.1.6 Alignment

Alignment is assessed by statistically comparing the judgments of manufacturing companies to those judgments made by industrial engineering academia and industrial engineering students at the senior and graduate level.

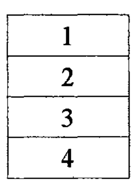
3.2 Research Plan

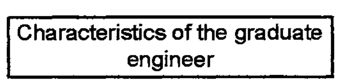
The research plan is the overall scheme for this research. It details the course of action to accomplish the objective and sub-objectives. Table 3.2 works in concert with Table 3.1 to define the research algorithm.

Table 3.2 Summary of Saaty's (1985) Analytical Hierarchy Process Defined for the Research Project

Step #	Task
1	Define the problem and the desired solution.
2	Structure the hierarchy as an overall management perspective, starting from the top, through (the) intermediate level(s), to the bottom level at which intervention is possible. This is accomplished by broadly defining sets of criteria that influence the problem.
3	Construct a set of pairwise comparison matrices of the characteristics of the industrial engineering candidate for each of the lower levels for each element in the level immediately above (See Table 2.5). There are $n(n-1)/2$ pairwise comparisons, "judgments", required to develop each matrix.
4	Obtain all judgments required to develop the set of matrices called for in "step 3".
5	Following the collection of all pairwise comparisons, obtain the priorities and test for consistency.
6	Complete steps 3, 4, and 5 for all levels of the hierarchy.
7	Synthesize the hierarchy to weight the vectors of priorities by the weights of the criteria.

Figure 3.1 models the relationships to be analyzed by the research. Three populations are tested: student, school, and factory. The following key explains the figure's shapes and/or text:

- **Student** = Undergraduate and graduate industrial engineer enrolled in graduate-level courses.
- **Factory** = The manufacturer
- **School** = Higher education, industrial engineering academician
- **Expectations** = population of desired characteristics of the graduate-level industrial engineer.
- 

= The key characteristics of the graduate-level industrial engineer.
- 

= A summary comparison

Three populations are used to study the goal. By triangularization, the author attempts to positively contribute to the validity and verification of the qualitative data through checking the consistency of the data using different sources (Patton, 1980).

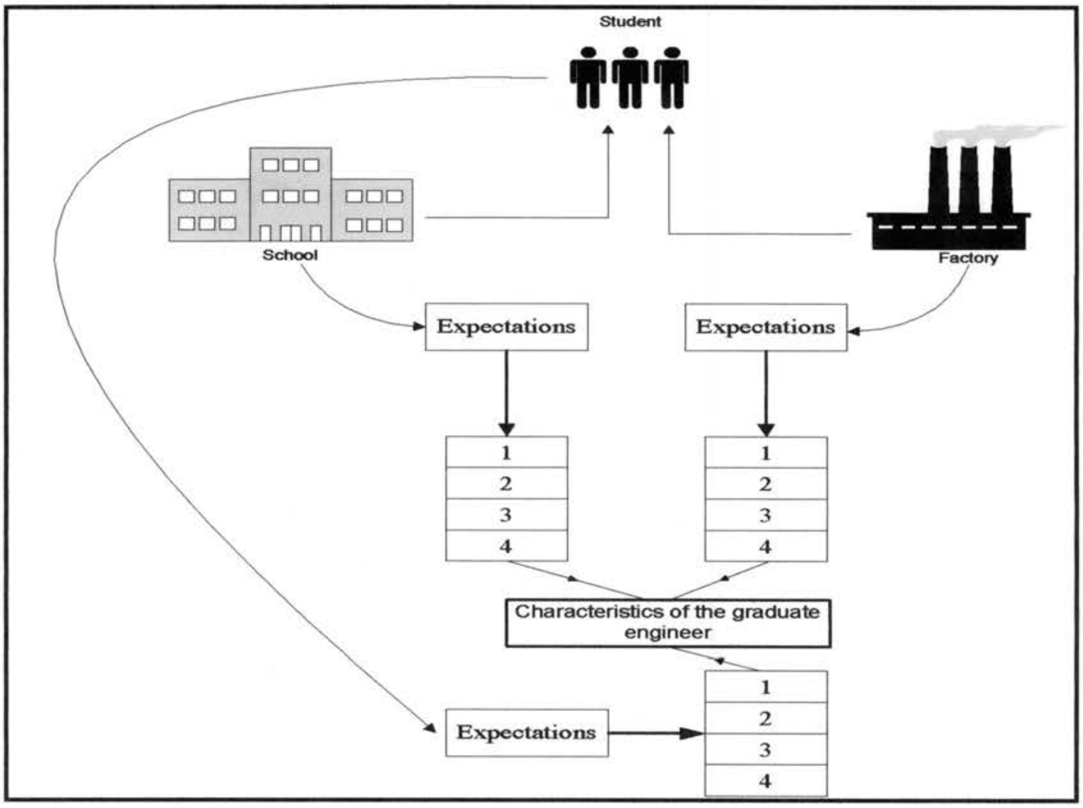


Figure 3.1 Model of Research Comparisons

3.2.1 Step 1: Develop Questions about Goals Alignment between the Stakeholders

In this step, an approach to sub-objective 1 is addressed; Saaty step 1 is linked to Step 1. To research the alignment between the stakeholders, it is necessary to understand what goal (focus) exists for each stakeholder and to find a means to reach consensus on each, should there be differences in the stakeholder groups or between the groups (Saaty, 1986). In other words, we should ask, "What is the situation about which a solution is needed." Each customer ["stakeholder"] may have differing goals in mind about an engineering program aligned to their individual needs. As a result, the author opted to evoke stakeholders' verbal responses and to organize their opinions about stakeholder group goals and the factors that may bear upon the goals. Based on Baldrige (Baldrige, 2002) educational criteria and the author's definitions for *alignment* and *student*, the "student" was selected as that product of the engineering higher education process key to meeting the research objective.

3.2.2 Step 2: Develop a Survey Research Plan.

Puerzer and Rooney (2002) report on the effectiveness of an alumni survey for engineering programs. Their approach was to take ABET EC2000 criteria and have alumni self-report the importance of and their preparedness for the ABET criteria. However, their approach was limited to identifying areas of significant perceptual differences rather than specifying engineering skills. This research expands upon the research of human subjects by segmenting alumni and by specifying desired graduate-level industrial engineering skills as those agreed upon by participating research groups.

The following lists the survey planning process steps and a macro-perspective on the research (Warde, 1990):

- The objective of the survey was to determine the most important characteristics of the graduate-level industrial engineer.
- The survey population consisted of the higher education stakeholders: academicians, manufacturers, and students. Alumni participants were selected based solely upon their meeting the definitions of *expert panel-academia* and *expert panel-manufacturing* (See "List of Definitions"). Observations from the student population met the definition of *student*.
- The survey was financed out-of-pocket; no external support.
- The timing of the survey was estimated at six months.
- The author constructed the survey.
- The author pre-tested the survey with selected expert industrial engineering professionals representing academia and manufacturing populations and a student representative to validate the soundness of the survey instrument for the purpose of establishing internal validity. That is, are the characteristics of the engineer judged by the respondent in the actual survey a reasonable approximation of the population of graduate-level engineers?
- The population frame was decided upon as follows: (Please note that data confidentiality and/or anonymity met the plan submitted to and approval given by the Oklahoma State University Institutional Review Board (See Appendix A – "Oklahoma State University Institutional Review Board {IRB}Form for Research Involving Human Subjects"))
    - Expert panel-academic: The academicians should be selected from a frame representing higher educational institutions from the states in which the manufacturing panel and students are located, plus contiguous states. While this may limit the generalizability of the results, the author assumed that these academicians may better understand the needs of those manufacturers located proximate to their institution.
    - Expert panel-manufacturing: The manufacturers should be selected from a frame representing manufacturers from the states in which the other panel and students are located, plus contiguous states. While this may limit the generalizability of the

results, the author assumed that these manufacturers may better understand the needs of those industrial engineering departments located proximate to their manufacturing site(s).

  - Student: Individuals meeting the definition of student and representing higher educational institutions from the states in which the other panel members are located, plus contiguous states. While this may limit the generalizability of the results, the author assumed that these students may be more familiar with the needs of those manufacturers located proximate to their institution. The author understood the potential for bias in the results, which is addressed in the "Conclusions and Recommendations."

- Following IRB approval, the author collected the data, assisted by a data-entry clerk, who also served to cross-check the accuracy of the data. (See Chapter 5, Section 5.1).
- The author analyzed the data using commercially available software installed on institutional and domestic PC systems. (See Chapter 5, Section 5.1).

3.2.3 Step 3: Develop Requirements for Academia, Employer, and Student Stakeholders.

This step attempts to add to the research of sub-objective 1. To understand the process of obtaining a consensus of opinion from a consuming stakeholder and to select a "best" method requires: surveying commonly used tools for consensus decision-making; and surveying the population for tools that provoke ideas towards reaching group consensus decisions (Brassard & Ritter, 1994).

The following lists tools used in group decision-making:

- Activity Network Diagram
- Affinity
- Brainstorming
- Cause & Effect/Fishbone
- Flowchart
- Forcefield
- Gantt
- Interrelationship Digraph
- Matrix
- Nominal Group Technique (NGT)
- Prioritization
- Process Decision Program Chart
- Radar
- Tree

While the final decision on the "best" tool is somewhat arbitrary, tools that take advantage of the dynamics of a natural group can use the positive aspects of that group as a starting point (Kleiner &

Shewchuk, 2001). This research anticipated that the manufacturing group(s) would already have a corporate relationship. As a result, the NGT tool was selected, because among the tools listed above, NGT improves the group consensus process (Kleiner & Shewchuk, 2001). In addition, face validity of the characteristics of the graduate-level engineer can be established, because the researcher will facilitate a meeting in which the participants in the expert panel will reach consensus on the characteristics and definitions of the characteristics.

3.2.4 Step 4: Develop an AHP Hierarchy.

From Step 3, the characteristics defining the engineer will be known. Further, the group will reach consensus on the hierarchical relationship between the characteristics. A hierarchical pattern among these characteristics may then be constructed similar to Figure 2.2, page 47. Saaty step 2 is linked to this step. (See Figure 3.2).

3.2.5 Step 5: Develop a Research Instrument Based Upon the AHP Hierarchy.

Given the hierarchy developed in Step 4, develop a research instrument that assesses a respondent's self-reported judgments, that is the pairwise comparisons between the characteristics of the hierarchy's goal – level 1. (See Figure 2.2, page 47). To repeat, then, the goal [the question the respondent will ask themselves while completing the survey] is as follows, "What are the characteristics of the ideal graduate-level industrial engineer presenting themselves to an employer directly following graduation?" Because the author anticipated the research of primarily qualitative characteristics of the engineer, it was important to ensure that the characteristics were well defined by the expert panel – manufacturing to improve the independence between the elements comprising the set of characteristics. Saaty concedes that the "…criteria in the AHP are mutually exclusive but that does not imply that they are dependent" (Saaty, 2000, page 126). Compiling a thorough description of the elements of the hierarchy would help prevent erroneous judgments (Saaty, 2000).

Further, the validity of the subjective measure is improved with "…questions as reliable as possible" (Fowler, 2002, page 101). A description of the elements of the hierarchy, a definition of the characteristics, should be included in the survey for respondents to review as they completed the survey.

3.2.6 Step 6: Pretest the Research Instrument.

Conduct a preview of the research instrument using individuals representing the population's expert panels. This may be an iterative step comprising several re-tests to assure clarity. Request and respond to comments made by the participants.

3.2.7 Step 7: Execute the Survey Research.

Distribute the research instrument using a method most assured of achieving responses from the survey frames (Warde, 1990). It is anticipated that United States Postal Service Priority 2-day mails will be used. Included in a mailer may be a pre-paid 2-Day Priority envelop to demonstrate the author's commitment. It is also anticipated that personal telephone calls will be used to provoke response from non-response participants. Incomplete surveys will be returned to the respondents with a cover letter explaining the reasons for the return. Priority mailings will again be used.

A decision rule will be required for discrepancies between the verbal and numerical judgments given the pairwise comparisons. For example, a respondent may assess two characteristics as equally weighted, A=B. However, their Saaty scale score does not = 1. The author arbitrarily chose to use the verbal description over the numerical score. That is, in the previous case, if the respondent had selected a verbal judgment that said A=B, but the numerical score was not "1", then the particular survey response in that case was changed to a "1". This action is in concert with research reported elsewhere (Leepatanapan, 1997).

3.2.8 Step 8: Gather Data from the Survey Instruments.

Surveys will be coded as they arrive. The author will send an appreciative letter to each respondent. Surveys will be protected in accordance with the plan submitted to and approved by the OSU IRB.

3.2.9 Step 9: Prepare the Data for Insertion into an Expert Choice© PC Application.

The author's data assistant will assist in the quality checking of data entry. Saaty steps 3 and 4 are linked to this step.

3.2.10 Step 10: Develop hypotheses about the alignment of goals between the stakeholders.

Alignment is assessed by statistically comparing the judgments of manufacturing companies to those judgments made by industrial engineering academia and industrial engineering students at the senior and graduate level.

Sub-objectives 2, 3, and 4 are researched at this step.

Hypotheses should be drawn regarding the similarity between the stakeholders. That is, check agreement on a common set of expectations [the "Goal", level 1 in AHP terminology] in regards to the criteria needed for the graduate-level industrial engineering student being presented as a candidate for an engineering position after graduation.

Saaty steps 5, 6, and 7 are linked to this step.

3.2.11 Step 11: Analyze Each Research Instrument.

Conduct an analysis of each instrument using Expert Choice© enabled AHP. Develop a group judgment for each stakeholder sample, for each level 2 characteristic.

Sub-objectives 2, 3, and 4 are researched at this step.

3.2.12 Step 12: Develop and Execute Statistical Analyses.

Assess the data for assumptions of normality, equal variance, and equal sample size. Select statistical tests that recognize the data without severe departures from those assumptions. Test the hypotheses using the test statistics.

Sub-objectives 2, 3, and 4 are researched at this step.

3.2.12 Step 13: Draw and State Conclusions.

Answer the question, "What is the importance of the findings?" Sub-objectives 2, 3, 4 and 5 are researched at this step.

Chapter 4. Development of the Methodology

4.1 Introduction

The purpose of the chapter is to develop the research methodology introduced in Chapter 3. Table 4.1 extends Table 3.1, "Research Plan," by including a column titled "Research Phase." The term "Research Phase" was given by the author to: summarize; temporally sequence; classify the work accomplished in the research; and to report the interrelationship of the steps in the research plan. The "Sub-objectives" are stated in Section 1.4. See Figure 4.1, which models the research process. The discussion in this chapter follows the column titled "Research Phase". The other columns, then, track along with the discussion as the research unfolds.

Table 4.1 Research Plan: Development of the Methodology

Step	Description of the Step	Saaty Step	Research Phase	Sub-Objective
1	Develop questions about the alignment of goals between the stakeholders.	1	I	1
2	Develop a survey research plan.		I	
3	Develop requirements for academia, manufacturer, and student stakeholders.		I	1
4	Develop an AHP hierarchy.	2	I, II	
5	Develop a research instrument based upon the AHP hierarchy.		I, II	
6	Pretest the research instrument.		I, II	
7	Execute the survey research.		III	
8	Gather data from the survey instruments.		III	
9	Prepare the data for insertion into an Expert Choice© PC application.	3, 4	III	
10	Develop hypotheses about the alignment of goals between the stakeholders.		III	2, 3, 4
11	Analyze each research instrument.	5, 6, 7	III	2, 3, 4
12	Develop and execute statistical analyses.		III	2, 3, 4
13	Draw and state conclusions			2, 3, 4, 5

4.2 Discussion of the Research Phases

Figure 4.1 charts the research flow and illustrates the interrelationships between its phases.

- **Phase I**. This phase comprises the collection of the data from an NGT session (Appendix 2) that built the principle and dependent characteristics of the engineer. At this session, an affinity diagram session was also used to group the characteristics under their parent characteristics. At the conclusion of step 1A, an initial "AHP Hierarchy" was built and discussed (Steps 1B & C). A revised hierarchy was delivered (Phase II) to the same cohort after several weeks of time to consider the session.
    - A representative sample of academicians and students was also selected during this phase, but did not participate in the data collection. Sections 4.3 and 4.4 detail the research done in this phase.
    - "1 Out" shows the flow of the revised hierarchy to the following phase.
- **Phase II**. This phase comprises the evolutionary development of the final research instrument. The "Tinker Cohort" provided modifications to the hierarchy (Appendix 6). Section 4.5 details the research done in this phase.
    - "2 Out" shows the flow of the final hierarchy to Phase III.
- **Phase III**. This phase comprises the process of mailing the research instrument to the research participants and analyzing the results. Of note is the segmentation of the manufacturing population into two participant populations: "Tinker", which represents the sample of industrial engineers from the Oklahoma City Air logistics Center; and "Boeing IDS", which represents the Boeing – Saint Louis, MO Integrated Defense Systems Division [Note: the inclusion of Boeing IDS is discussed in Section 4.4]. "Graduate Student" represents the cohort of graduate students in the author's graduate industrial engineering course. "UG Student" represents the cohort of undergraduate students in the author's graduate industrial engineering course. Section 4.6 details the research done in Phase III.
    - "3 Out" depicts the flow of the weighted attributes from each group to an "Output" phase in which analyses are completed.

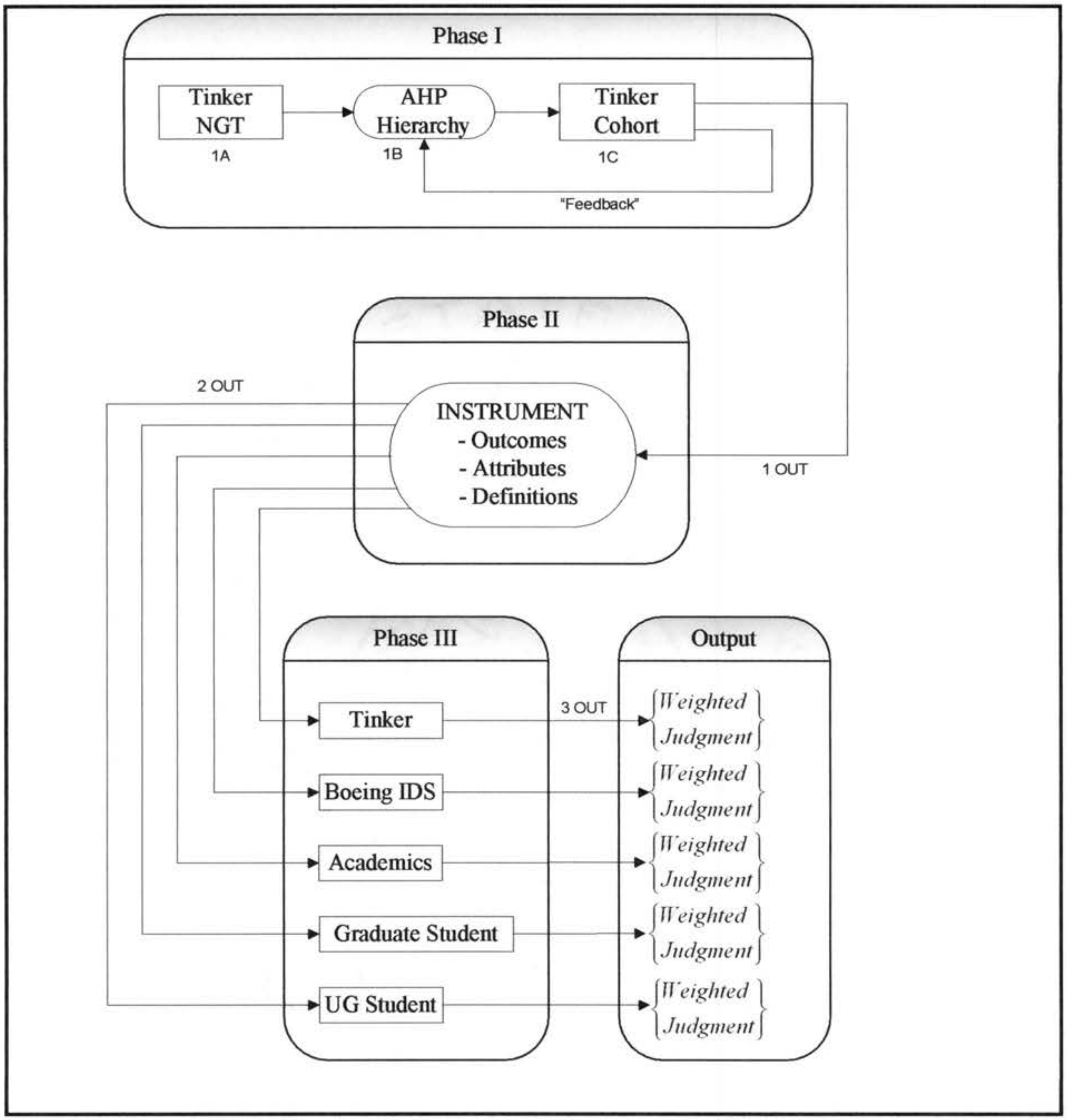


Figure 4.1 Model of Research Instrument Development and Data Collection

4.3 Phase I

Figure 4.2 excerpts Figure 4.1 to illustrate the main components of Phase I of the research.

4.3.1 Preliminary discussions:

Research was conducted to determine the use of an AHP-based survey instrument. Primarily, this phase was used to verify the initial conclusions [by the author], that there were technical and non-technical characteristics of the industrial engineer that could be sourced with the manufacturer. Further, the concept of a hierarchical decomposition of the goal, "Characteristics of the graduate-level I.E. employment candidate", was explored. This phase concluded with a consensus that the primary characteristics of the industrial engineer at the graduate-level comprised a technical, managerial, social, and political characteristic set. Also, it was concluded that the goal could be decomposed, but that the definitions of the attributes ("characteristics") and their sub-attributes had to be carefully made so as to reduce individual bias and questions of dependence between the characteristics. Also, it was found that a careful definition of the terms in the hierarchy would be critical in order to minimize the potential for follow-on participants' biases resulting from confusion on explicit definitions for all characteristics. The researcher and his assistant carefully copied the consensus of opinions regarding the definitions for all characteristics. Further, a future mailing to the participants in this Phase asked that they review and comment upon the definitions. Their proposals were melded into the final set (Phase III) of definitions for the final research instrument.

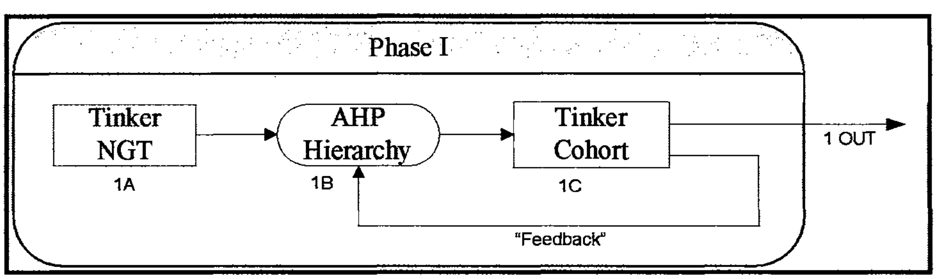


Figure 4.2 Research Phase I Model

Further, during this phase, preliminary contacts were made with a sample of academic experts. They were selected from a group representing all industrial engineering departments offering graduate-level degrees from institutions situated in those states immediately contiguous to the State of Oklahoma. This was done so as to account for any expressed bias in the manufacturer's data resulting from their primarily hiring students from those institutions proximate to the place of employment.

Finally, it was during this phase that the stakeholder of students was selected from the class of students instructed by the author at a research institution in the Midwest United States.

4.3.2 Phase 1: Manufacturing Focus Groups

To obtain the data for the manufacturing side of this research project, a focus group was formed at the Oklahoma City Air Logistics Center with a panel of selected industrial engineers fitting the description of "expert" as was defined in the Chapter 1, Section 1.5. A process known as the Nominal Group Technique [NGT} was used to identify a consensus on the common areas of interest in the graduate engineering candidate for the "group's" business. The manufacturing stakeholders focused upon the following NGT question:

"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"

Figures 4.2.1 through 4.2.5 report the in-depth briefing provided the participants and, with the exception of Figure 4.2.4, are given without further explanation (Note the numbers appearing at the bottom right corners, for example "3", "4", "5", and so on are the page numbers from the briefing. Pages 1 and 2 were the briefing's title and outline pages, respectively. These pages are not included):

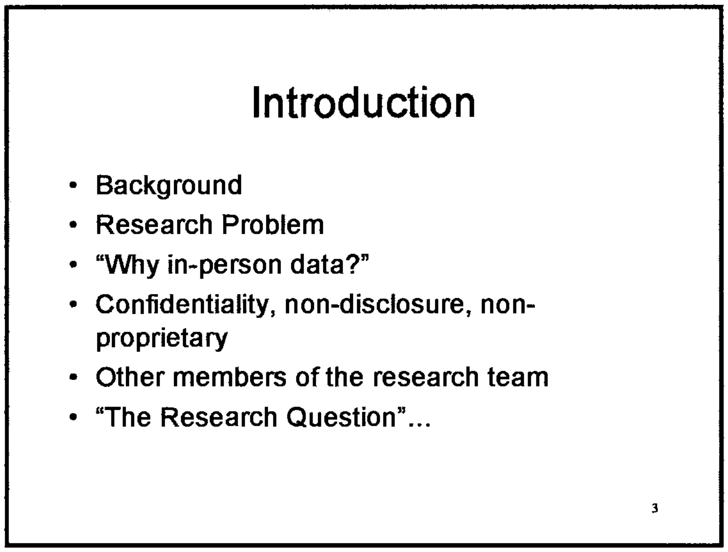


Figure 4.2.1 Briefing: Introduction

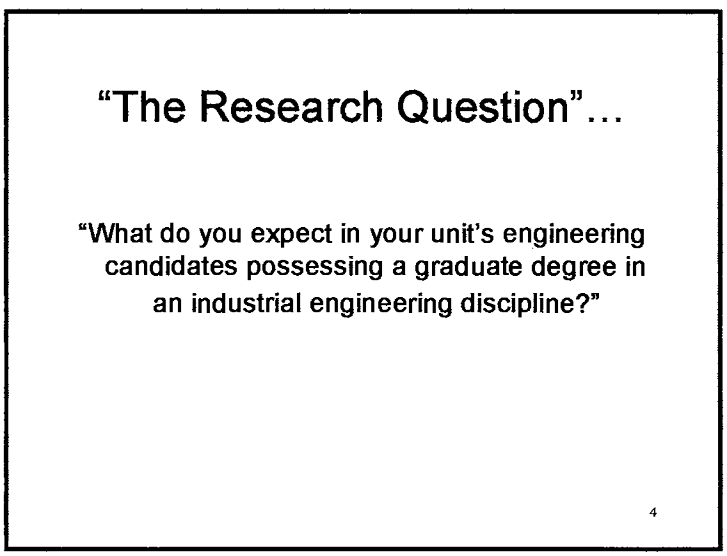


Figure 4.2.2 Briefing: Research Question

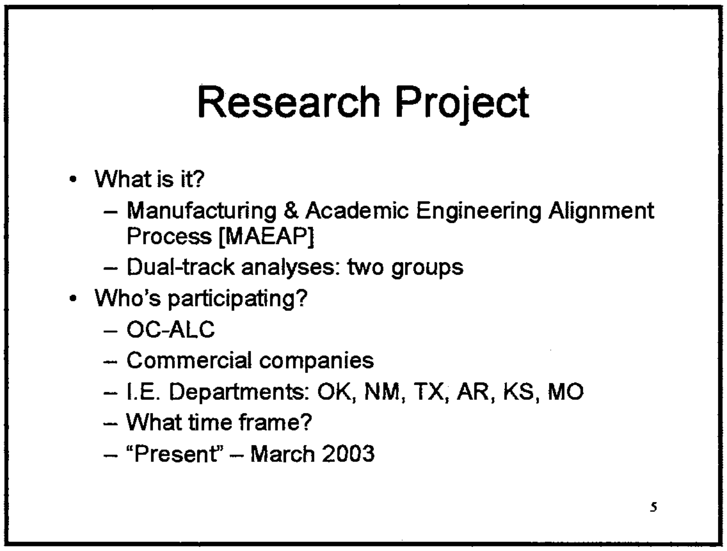


Figure 4.2.3 Briefing: Project Overview

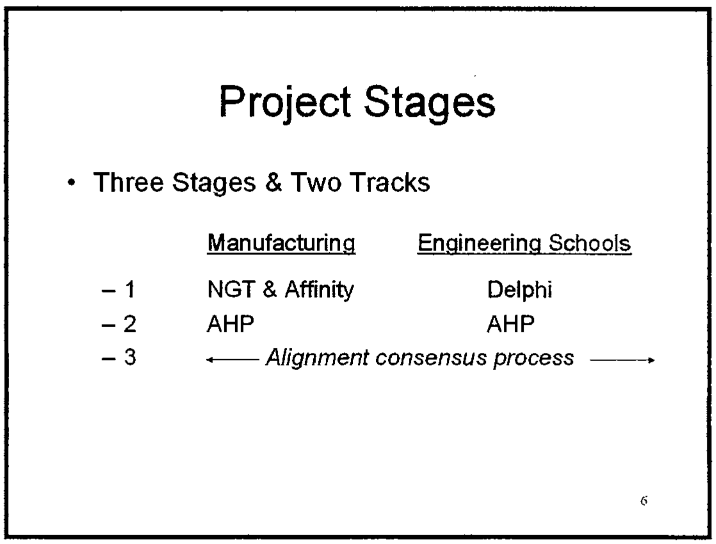


Figure 4.2.4 Briefing: Project Stages

A change was made to the methodology prior to Phase I that eliminated the use of the "Delphi" method noted in Figure 4.2.4, in the column titled "Engineering Schools". This change was briefed to the manufacturing participants. The reason for this change was due to the time in the academic semester in which the Delphi method would have been accomplished. Telephonic contact with several potential participants revealed scant support for the time demanded of this technique. A cohort of participants could not be formed.

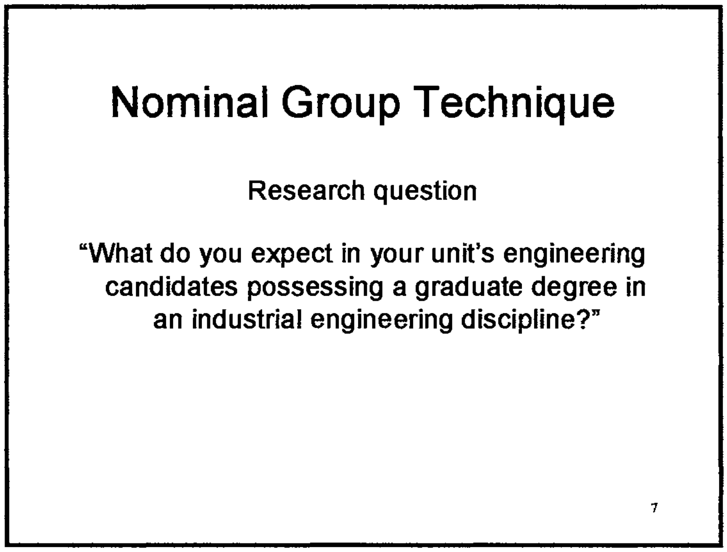


Figure 4.2.5 Briefing: NGT Research Question

NGT is a commonly used group consensus process when individuals are drawn together to form *ad hoc* groups in name only for the purpose of attaining consensus on some issue under consideration (Scholtes, Joiner, & Streibel, 2001). Numerous references document the use of NGT in many settings. In a recent example, Dr. Leva Swim, Director, Decision Support, Integris Health, Oklahoma City, Oklahoma [and Ph.D., industrial engineering] used NGT and AHP to develop a consensus and vote on the ways to decide upon energy management projects for a local medical center [Structured interview, July 9, 2002]. Dr. Swim had previously conducted thirty-five NGT sessions over an eight-year period covering a variety of consensus-building topics.

The decision to use NGT versus other forms of group consensus processes, such as mailed or telephone surveys, was based upon a test panel of academic and manufacturing experts as follows: discussions with Dr. Swim and other in-person, structured interviews with Dr. Terry Collins [July 15, 2002, Department of Industrial Engineering, University of Arkansas]; Mr. Jim Henderson [July 11, 2002, Oklahoma State University]; Mr. Bob Carter [August 8, 2002, Oklahoma County Field Agent, Oklahoma Alliance for Manufacturing Excellence]; Dr. Steve Agee, President, XER Petroleum, Oklahoma City, Oklahoma [August 1, 2002]; Dr. Inslee Bennett, Managing Principal, Leader Communications, Incorporated [August 7, 2002]; Dr. Saba Bahouth, [August 15, 2002] Chair, Department of Information Systems and Information Management, University of Central Oklahoma; Dr. Tim Bridges, Associate Dean, College of Business, University of Central Oklahoma [December 11, 2002]; and Dr. Jerry Allison, [August 15, 2002] Assistant Professor, Department of Information Systems and Information Management, University of Central Oklahoma. These discussions were held by the author at the interviewee's place of academic assignment or a neutral site of their choosing. In each case the information garnered from the others was not shared.

The general consensus was that the manufacturing and academic communities would agree on a four point set of characteristics classifying their expected needs in the graduate-level engineer:

- Technical,
- Managerial,
- Political, and
- Social.

The author then proceeded to locate working definitions for these characteristics. What resulted was sourced from a variety of researchers in the area of managerial decision-making.

Robbins and De Cenzo (2001) give the following definition to these terms:

- Technical Competence: The ability to apply specialized knowledge or expertise.
- Political: Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.
- Conceptual: Ability to analyze and diagnose complex situations.
- Managerial: Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Rue and Byars (2001) argue for these definitions:

- Technical skills: Knowledge about machines, processes and methods of production.
- Human Relations skills: Ability to get along with people and knowledge about human behavior.
- Administrative skills: Knowledge about the organization and how it works.
- Decision-making and problem-solving skills: ability to analyze information and to objectively reach a decision.

Certo (2000) provides a slightly different focus as he defines terms similar to the above list as:

- Technical skills: Specialized knowledge and expertise used to carry out particular techniques or procedures.
- Human Relations skills: Ability to work effectively with other people.

- Conceptual: Ability to see the relation of the parts to the whole and to one another.
- Decision-making skills: Ability to analyze information and reach good decisions.

These three definition sets were proposed to the manufacturing panel during the December, 2002 NGT data collection session. Following that session, the following definition set resulted by consensus:

- **Technical skills**: Specialized knowledge and expertise used to carry out particular techniques or procedures.
- **Managerial**: Ability to get things done by planning, organizing, directing, and controlling others in the organization.
- **Social Competence**: The ability to work with, understand, communicate with and motivate other people, both individually and in groups.
- **Political**: Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.

Later in Phase II, additional opportunity was provided the manufacturing panel to modify their agreement; however, none did (Appendix 9).

4.3.3 NGT and Affinity Session

The *technical, managerial, social,* and *political* characteristics provided a starting point for facilitating the manufacturing groups' hierarchical judgments, as noted below. Further, and more importantly to the success of this research, these characteristics provided an "affinity" heading that was used to further classify those criteria to be identified by the manufacturing expert panel. For purposes of the research, the *technical, managerial, social,* and *political* characteristics comprise the first hierarchical level [level 2] below the goal [See Figure 2.2]. This assumption is explained later in this chapter.

The commonly used NGT process documented in (Scholtes, Joiner, & Streibel, 2001) and other references was employed as given in NGT Phase I – Idea Generation and NGT Phase II – Priority Setting [Note, please do not confuse the NGT process classifications of Phase I and II with those terms given to stages of this research project. They are not directly related]. The one major exception to the commonly used NGT process was in NGT Phase II- Priority Setting. The reason for this modification was that if the commonly used NGT process were used without exception, then at this point in the session the participants would have voted on a prioritization of the ideas in order to rank them from the most important to the least important issues and the session would have concluded. Normally, NGT sessions end with a scaled list, prioritized from the top issue to the last. This step focuses the group on optimizing organizational resources in a prioritized list.

However, in this research and in the interest of time, another group decision-making process tool was immediately introduced – "Affinity Diagramming" (Brassard & Ritter, 2000). Affinity diagrams are one component of the quality community's "Seven Management Quality Tools" (numerous references). Figures 4.2.6, 4.2.7, and 4.2.8 depict the briefing points presented the participants. This research sought the weighted comparative judgments of the group within an overall hierarchical structure of the group's making, because **there was no research literature found that argued for a prioritized hierarchy of graduate-level industrial engineering skills**.

The research project's manufacturing participants agreed to continuing in one data collection session. As a result, the affinity diagram provided the initial NGT hierarchy with the qualitative outcomes expected from the group.

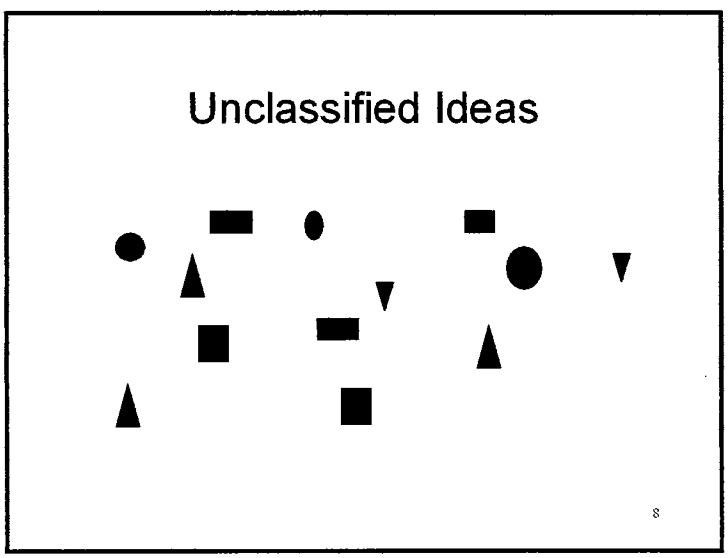


Figure 4.2.6 Briefing: Unclassified Ideas Model

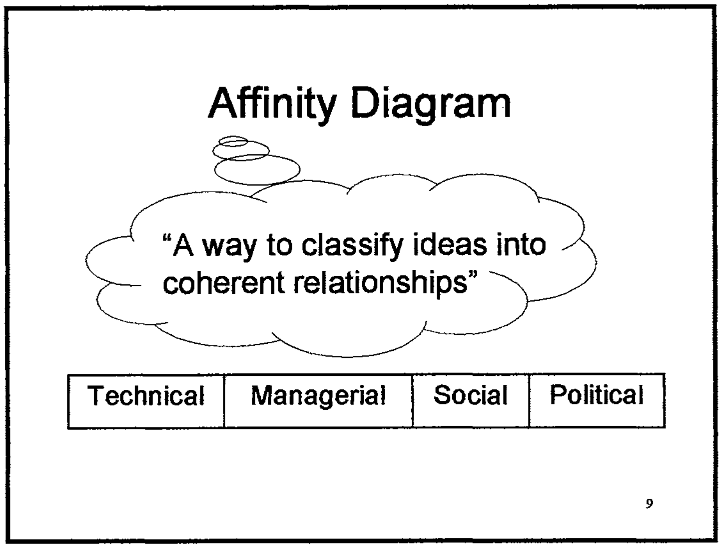


Figure 4.2.7 Briefing: Affinitization Diagram, Part 1

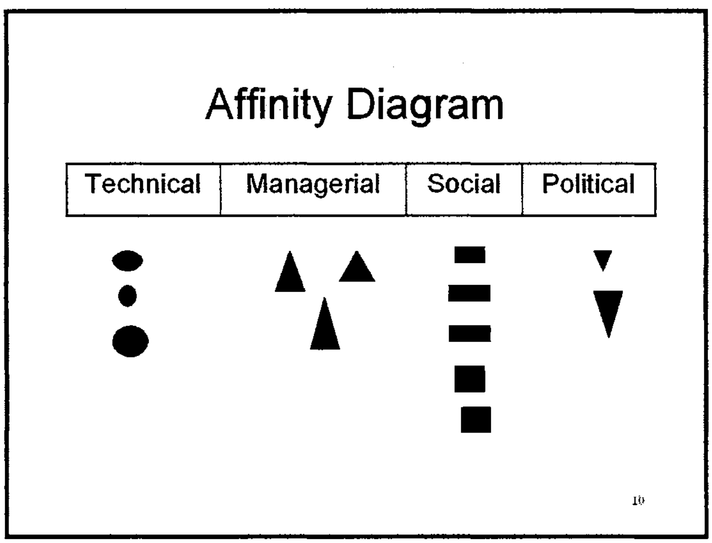


Figure 4.2.8 Briefing: Affinitization Diagram, Part 2

The four points described by the expert panels and verified by the test group [technical, managerial, political, and social expertise], then, form a level of hierarchy below which are seen the specific elements agreed upon by the expert manufacturing panel. Figures 4.2.9 and 4.2.10 concluded the data collection session and illustrated the structure of the hierarchy as given by the participants. Section 4.4 with Figure 4.2 provides more explanation about the results of this data collection session.

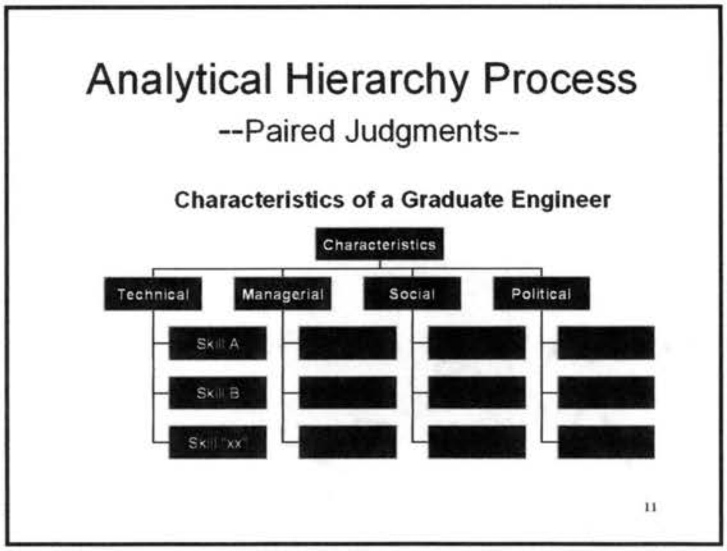


Figure 4.2.9 Briefing: AHP Model, Part 1

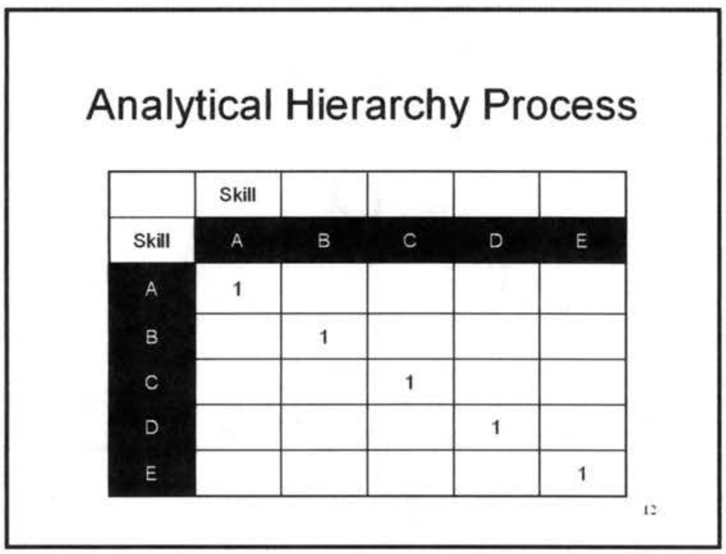


Figure 4.2.10 Briefing: AHP Model, Part 2

4.3.4 Academic Focus Groups

An expert panel was assembled that represented higher education. While not participating in the NGT/Affinity sessions, they operated in Phase I in parallel with the manufacturing focus group to provide validation of the characteristics initially output. Members of this panel included several of those also represented on the manufactures' panel because of their previous experience in manufacturing. All members had earned a Ph.D. in industrial engineering: Dr. Terry Collins, Assistant Professor, Department of Industrial

Engineering, University of Arkansas; Dr. Saba Bahouth, Chair, Department of Information Systems and Information Management, University of Central Oklahoma; Dr. Tim Bridges, Associate Dean, College of Business, University of Central Oklahoma; and Dr. Jerry Allison, Assistant Professor, Department of Information Systems and Information Management, University of Central Oklahoma. Members of this panel had originally assisted in providing the initial characterization of the graduate-level engineer as: *technical, managerial, social,* and *political.* Finally, the panel also assisted later in research Phase II to validate the survey.

4.3.5 Group Hierarchy Judgments.

To develop the hierarchy of pairwise comparisons, the affinity diagrams clustered the groups' ideas within logical, natural clusters. This is a primitive technique when a scarcity or lack of *a priori* information is known about the groups and when the information is primarily qualitative in nature (Tedesco, 1998). As previously stated, four general areas resulted from the test panel: *technical, managerial, social,* and *political.*

4.4 Summary and Follow-on Actions to Phase I

Oklahoma City Air Logistics Center (OC-ALC) is the largest employer in the State of Oklahoma in terms of both gross revenues and numbers of employees and, in particular, industrial engineers. A list containing numbers of engineers and scientists for the three United States Air Force Logistics Centers is found at Attachment 3.

An NGT session was completed at the worksite of the participants – OC-ALC/TIE in the office of Dr. Wayne Jones. The "characteristics of the graduate-level I.E. employment candidate" was introduced and discussed for approximately two hours. Following clarification of their definitions, they were decomposed into a set of sub-attributes. Appendix 2 contains the script used in the NGT session. Appendix 3 contains the initial letter and attachments sent to the OC-ALC center point-of-contact, Dr. Wayne Jones. During the session, in order to shorten the time to completion, the primary level characteristics were discussed in a round-robin fashion so that the decomposition into sub-attributes would simultaneously occur. This is a form of the commonly used Affinitization process and has been successfully used to source participants' ideas in one data collection session (Swim, 2003).

This phase concluded with four primary characteristics and 60 sub-attributes unequally distributed among their "parent" attributes. See Appendix 4 for the results of this session. Also, during this phase, extensive conversations with the manufacturing stakeholder led to the decision to develop another stakeholder of manufacturers representing the immediate supplier population to the manufacturer. This was accomplished due to the fact that the initial manufacturing stakeholder was representative of the United States federal sector at the Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma. Also, the researcher felt that it would be appropriate to include this supplier: demographically they are similar. It was also decided to pool the responses of the two manufacturers, because the commercial supplier to the federal manufacturer was 100% obligated to support United States military products. This is an assumption listed in Chapter 4, Section 4.11, "Assumptions and Limitations". Table 4.2 lists the *verbatim* results from this phase copied from chart paper affixed to the walls of Dr. Jones' office.

Table 4.2 Affinitized Results of the Nominal Group Technique Session at OC-ALC, 18 Dec 02

Technical	Science & math background
	Application of the basics
	Technical expert in particular field [skill]
	Able to define the problem – problem solving overall
	Able to analyze using specific tools – economic engineering, risk analysis
	Computer literate
	Knowledge of industry standards
	Able to sell ideas to others
	ISO 9002
	Failure analysis techniques
	Be trainable
	Hands on experience – internships/co-ops
	Hands on experience – machining, lathe, milling @ vo-tech
	Did you have "real world" experience b/w degrees?
Managerial	Problem solving skills: breaking down into smaller elements
	Able to analyze (i.e. engineering economics)
	Plan a project, manage projects and budget estimates
	Understand lean management in an overall environment
	Understand the difference between repair and new manufacturing
	Self-motivated
	Seeks challenges/new ideas
	Be able to chair meetings [plan & direct]
	Multi-tasking [good time management]
	Smoothly transition roles as a leader and a team player
	Be trainable
	Skill as a mentor: help others/foster development beyond training
Political	ID people & relationships in a variety of organizations as resources
	Ability to convert organizational goals into source of influence: individual & teams
	Lack of political inclination (influence/respect vs. power)
	Be adaptable
	Able to maintain valuable alliances
	Knowledge of which "fight to fight" and which one "not to fight": pick your battles
	Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience
	Common sense

	Good attitude
	Create a "win-win" atmosphere
	Confidence and enthusiasm
	Relevant communication skills via computers [email]
	Form working relationships with a variety of people
	Aware and willing to "earn" respect in a manufacturing environment
	Communicate well both orally [info, persuasive] and written [info, persuasive]
	Sell ideas to others
	Be a team player
	Get along in professional dynamics: how to get along in a group and with individual
	Skill as a mentor: help others, foster development beyond training
	Listen and accept instructions
	Able to give and take constructive criticism: professionalism, do not take things personally

It may be concluded that out of Phase I, that the following steps were completed in the methodology (See Table 4.1):

- Step 1: Develop questions about the alignment of goals between the stakeholders. The characteristics of the graduate-level industrial engineering graduate were selected as the nexus of goals for stakeholders.
- Step 2: Develop a survey research plan. A plan was designed and executed to survey the academic, manufacturing, and student populations.
- Step 3: Develop requirements for academia, manufacturer, and student stakeholders. The NGT and affinity session were designed and executed.
- Step 4: Develop an AHP hierarchy. This was accomplished.
- Step 5: Develop a research instrument based upon the AHP hierarchy. This step was accomplished.
- Step 6: Pretest the research instrument. This step was accomplished.

4.5 Phase II

In this phase, the initial responses by the Oklahoma City Air Logistics Center stakeholder were refined by reference to an expert panel of academics and by another review with the stakeholder. Figure 4.5 illustrates the process. Appendix 5 contains the package sent to the academicians and Appendix 6 contains the package sent to the manufacturing participants at the start of Phase 2. Two academicians, Drs. Swim and Collins, agreed to participate in this review. The entire cohort of OC-ALC participants agreed to participate.

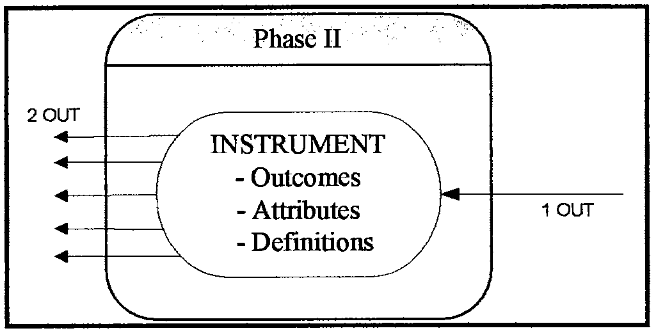


Figure 4.3 Research Phase II Model

A process line titled "2 Out" refers to the resultant product (survey of affinitized and hierarchy ranked characteristics sent Phase III participants). In addition, the "outcomes, attributes, and definitions" refer to the consensus review of the original findings from Phase I. Appendix 6 contains output from the self-reported reviews provided the author by each respondent of the OC-ALC manufacturing stakeholder.

4.5.1 Phase II Survey: Academic review

This survey (Appendix 5) followed up on the research (Phase I) conducted in mid-December 2002. It asked the respondent to comparatively judge between an engineering candidate's skills. The respondent was instructed to assume that these factors are gained solely through a graduate engineering education program. Further, the respondent was instructed to assume that the candidate is competing for a job in their work unit. The following discussion is quoted from the instructions given by the author to the expert academic participants for feedback.

"In this survey, the respondent makes comparative judgments between engineering factors on a scale ranging from 'extremely more important' to 'extremely less important'. For simplicity, judgments are represented by using the numerals 'plus 9' to a 'minus 9' in single digit increments, for example, 9, 8, 7...-7, -8, & -9. The numeral 1 is the midpoint and represents factors of about the same level of importance. For example, comparing a factor to itself would result in a judgment of '1'.

Let's look at a commonplace example facing ordinary consumers – 'purchasing a new car.'

Example Instructions

Several "factors" you could use to choose one vehicle over another might be **price, available options, standard equipment**, and so on. While each factor is important for making a final "best" decision, however, in comparing them side-by-side one factor might be more or less important than another factor. So, let's compare just **price** and **standard equipment**.

Example question #1.

'When buying a new car or truck, ***price*** is (how important) compared to ***standard features***?'

1	+2	+3	+4	+5	+6	+7	+8	+9
About the same		Slightly more important		Strongly more important		Very strongly more important		Extremely more important

1	-2	-3	-4	-5	-6	-7	-8	-9
About the same		Slightly less important		Strongly less important		Very strongly less important		Extremely less important

Please circle the number above which states your judgment about how important ***price*** is to ***standard features***.

Now, using the same rankings as, ***Example question #1,*** but removing the text:

Example question #2.

'When buying a new car or truck, ***price*** is (how important) compared to ***available options***?'

Circle your judgment."

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

The previous quoted material is taken from the initial survey using all of the characteristics provided the researcher by the Oklahoma City Air Logistics Center panel (Appendix 5).

4.5.2 Phase II Survey: Conclusion

The first structure of this survey comprised an instrument of over 250 comparisons and took 26 pages to print (Appendix 5). Table 4.2 illustrates the characteristics. The Project's Academic and Manufacturing experts who reviewed this preliminary survey negatively commented upon its length and suggested the strong possibility of an extremely low response rate.

An interesting outcome of the academician's review was their submission of responses the researcher requested to a series of reaction questions gauged to validate the responses given by the manufacturing panel.

The questions were included in a reaction sheet added to the survey Appendix 6). The sheet was divided into two parts. In Part 1, "Graduate Manufacturing Engineering Outcomes", the following two questions were asked and are given in the order presented in the survey:

- In the space below, please write down as many outcomes as possible, which should result in every engineering graduate student. Please attach additional sheets, if required.
- Please attempt to classify the outcomes you identified under general headings, such as theory, practice, ethics, communicative skills, etc. Please attach additional sheets, if required.

In Part 2, "Understanding the Alignment of Manufacturing Needs and Engineering Graduate Students", the following three questions were asked and are given in the order presented in the survey:

- In the space below, please write down the first five things that come to mind when you think about how close your engineering candidates currently match contemporary manufacturing companies' engineering needs.
- In the space below, please write down what you want in your engineering graduates in the role of candidates for manufacturing engineering employment.
- Considering the word "Alignment", please write down the first five things this word means to you when you read the following statement:

  "<u>Engineering schools and manufacturing must work together to have graduate students aligned to my manufacturing business requirements</u>."

Responses given these questions suggest a wide-ranging set of expectations:

- Part 1, question 1 and 2:
  - Engineering/technical
    - Problem solving
    - Understand engineering sciences
    - Analysis tools
    - Computer competency
    - Able to schedule manufacturing production
    - Familiar with manufacturing equipment
    - Facility layout and design

        - Workflow analysis
        - Cost estimating
        - Project management
        - Forecasting
        - Contacts on technical issues
    - Management
        - Small business entrepreneurship
        - Staffing
        - Benchmarking
        - Total Quality Management
        - Leadership development
        - Conflict resolution
        - Contacts on management issues
    - Social
        - Team work (interaction)
        - Motivational techniques
        - Interpersonal skills
        - Public speaking ability
        - Networking skills
        - Adaptable to changing work environments
        - Attitude towards work, i.e., white collar "social loafing"
    - Ethics
        - Understand engineering practice (ethical issues)
        - Know right from wrong
        - Contract law
        - Professional registration
- Part 2, Question 1
    - Technical competencies, engineering preparedness

- Problem solving
- Research Capabilities
- Managing projects
- Cost estimation

- Part 2, Question 2
  - Prepared for engineering challenges
  - Management skills
  - Communication skills
  - Team work environment
  - Easily adaptable to changing work environment
- Part 2, Question 3
  - Meet current needs of employer
  - Understand new technologies
  - Industry should provide feedback to universities through advisory boards on what they need in new grads
  - Ability to adapt to the fast-paced globally competitive environments of the manufacturing industry
  - Work on interdisciplinary cross-functional teams for process/product development

As a result, the author decided to review this survey with the original manufacturing respondent group. The time between the initial NGT/Affinitization session and the start of Phase II was approximately two months. This phase concluded with a refined instrument, redistribution of some of the sub-characteristics into sub-sub-characteristics, a few eliminations of sub-characteristics [perceived to be duplicates by the respondents] and re-clarification of the stakeholder's original definitions of the characteristics and sub-characteristics. Appendix 7 presents the material.

Also concluded was that the hierarchy should not be explored below the sub-characteristic level in order to reduce possible decision inconsistency within the groups and to reduce the time expected to complete the survey instrument. Saaty (1986) concluded that simplicity of the hierarchy would benefit the consistency of the decision. Further, at the December NGT session, participants "ran out of ideas". As a result of the

December session and the fact that no other ideas were proffered by the participants to "add to the characteristics", it was decided *post hoc* to maintain the hierarchy at two levels below the goal. This decision was shared with all Phase II participants with no dissention.

Table 4.3 reports the refined hierarchy.

Table 4.3 Hierarchical Model of Characteristics Expected by Employers in the Ideal Graduate-level Industrial Engineer Following Graduation

Technical	Science & math background
	Technical expert in particular field [skill]
	Knowledge of industry standards
	Failure analysis techniques
	Hands on experience – internships/co-ops
Managerial	Problem solving skills: breaking down into smaller elements
	Able to analyze (i.e. engineering economics)
	Plan a project, manage projects and budget estimates
	Understand the difference between repair and new manufacturing
	Self-motivated
	Smoothly transition roles as a leader and a team player
Political	ID people & relationships in a variety of organizations as resources
	Ability to convert organizational goals into source of influence: individual & teams
	Lack of political inclination (influence/respect vs. power)
	Able to maintain valuable alliances
	Able to work within a structure set by organizational rules and regulations
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience
	Common sense
	Create a "win-win" atmosphere
	Confidence and enthusiasm
	Get along in professional dynamics: how to get along in a group and with individual
	Listen and accept instructions
	Able to give and take constructive criticism: professionalism, do not take things personally

Also resulting from Phase II was consensus on the definitions to be used for all of the characteristics. Appendix 9 presents a complete survey and Table 4.4 presents the definitions of each of the characteristics and sub-characteristics used to assist the respondent to minimize bias.

Table 4.4 Definitions Determined by Manufacturing Expert Panel

Level 2	Level 3	Definition of Level 3
Technical	Science & math background	Received college-level academic credit for science and mathematics. Able to apply the basics: demonstrates practical evidence of using science, math, and engineering in practice. Able to analyze using specific tools – economic engineering, risk analysis: Able to use engineering formulae and processes basic to project management.
	Technical expert in particular field [skill]	Academic credit received for more than one course in subject area at the graduate level. Able to define the problem – problem solving overall: Able to show evidence of using a scientific method.
	Knowledge of industry standards	Is familiar with standards and codes used in the industry, not including international standards such as ISO.
	Failure analysis techniques	Familiar with Failure Mode and Effects Analysis (FMEA).
	Experience	Completed an internship or co-op experience. Demonstrated practical experience in basic skills such as machining, lathe operation, milling, and so forth. Following undergraduate degree, does the candidate have practical work experience?
Managerial	Problem solving skills: breaking down into smaller elements	Evidence of using scientific method
	Able to analyze (i.e. engineering economics)	Able to use methodological basic engineering formulae
	Plan a project, manage projects and budget estimates	Knowledgeable and demonstrate practical experience in project management skills. Be able to chair meetings [plan & direct] Multi-tasking [good time management]

Level 2	Level 3	Definition of Level 3
Managerial (cont.)	Understand the difference between repair and new manufacturing	Understands asset-driven and raw material manufacturing. Understands lean management in an overall environment
	Self-motivated	Works without supervisory oversight in most endeavors
	Smoothly transition roles as a leader and a team player	Shows ability to serve in multiple capacities
Political	ID people & relationships in a variety of organizations as resources	Able to show the relationship of people in various roles both inside and outside of the work unit. Knowledge of which "fight to fight" and which one "not to fight": pick your battles: Can show ability to manage projects with regard to "big picture" – compromise, risk, and consequences. Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground"): Served in a variety of projects internal and external to the work unit.
	Ability to convert organizational goals into source of influence: individual & teams	Can relate the overall mission into the operational procedures of the work unit.
	Lack of political inclination (influence/respect vs. power)	Able to show that work is related to the outcome of the unit and not to the improvement of one's resume'.
	Able to maintain valuable alliances	Able to show resource cooperation over a six-month period of time.
	Able to work within a structure set by organizational rules and regulations.	Able to positively impact organizational performance.
Social	Good communication skills: able to switch gears and direct communication appropriately to a change in audience	Able to speak and write to a variety of audiences. Able to sell ideas to others: Demonstrated experience as product or process champion. Completed training or academic credit courses in business communications.
	Common sense	Primarily uses data as basis of decisions, but allows for group consensus.

Level 2	Level 3	Definition of Level 3
Social (cont.)	Confidence and enthusiasm	Able to show proactive support for a group.
	Get along in professional dynamics: how to get along in a group and with individual	Practical experience in team projects. Form working relationships with a variety of people: Demonstrated membership in one or more groups within and without the work unit. Be a team player: Able to serve in a variety of roles in a work unit. Skill as a mentor: help others, foster development beyond training: Demonstrated experience as a trainer of others.
	Listen and accept instructions	Demonstrated experience in understanding procedures and project requirements.
	Able to give and take constructive criticism: professionalism, do not take things personally	Uses a variety of techniques to clarify and to reach consensus on requirements of tasks.

Figure 4.4 illustrates the research concluded to the end of Phase II. The four frames in the figure are explained as follows:

- **"Accepted"** = synthesis of extant literature resulting from a review of the literature. It says that there are two components to the characteristics of the engineer: "T" = technical; "NT" = non-technical.
- **"Theory"** = Research conducted prior to the start of Phase I suggests that the technical secondary level characteristic remains. However, the non-technical can now be refined into "M", "P", and "S" characteristics, which refer to managerial, political, and social characteristics, respectively.
- **"Phase I** = The level 2 characteristics were refined through the NGT and Affinitization process into Level 3 sub-characteristics shown as numbers in braces. For example T – {14} refers to the fourteen qualitative characteristics refining the technical characteristic.
- **"Phase II"** = A further refining of the Level 2 characteristics into a set made manageable for an AHP-based survey. A total of 23 attributes remained.

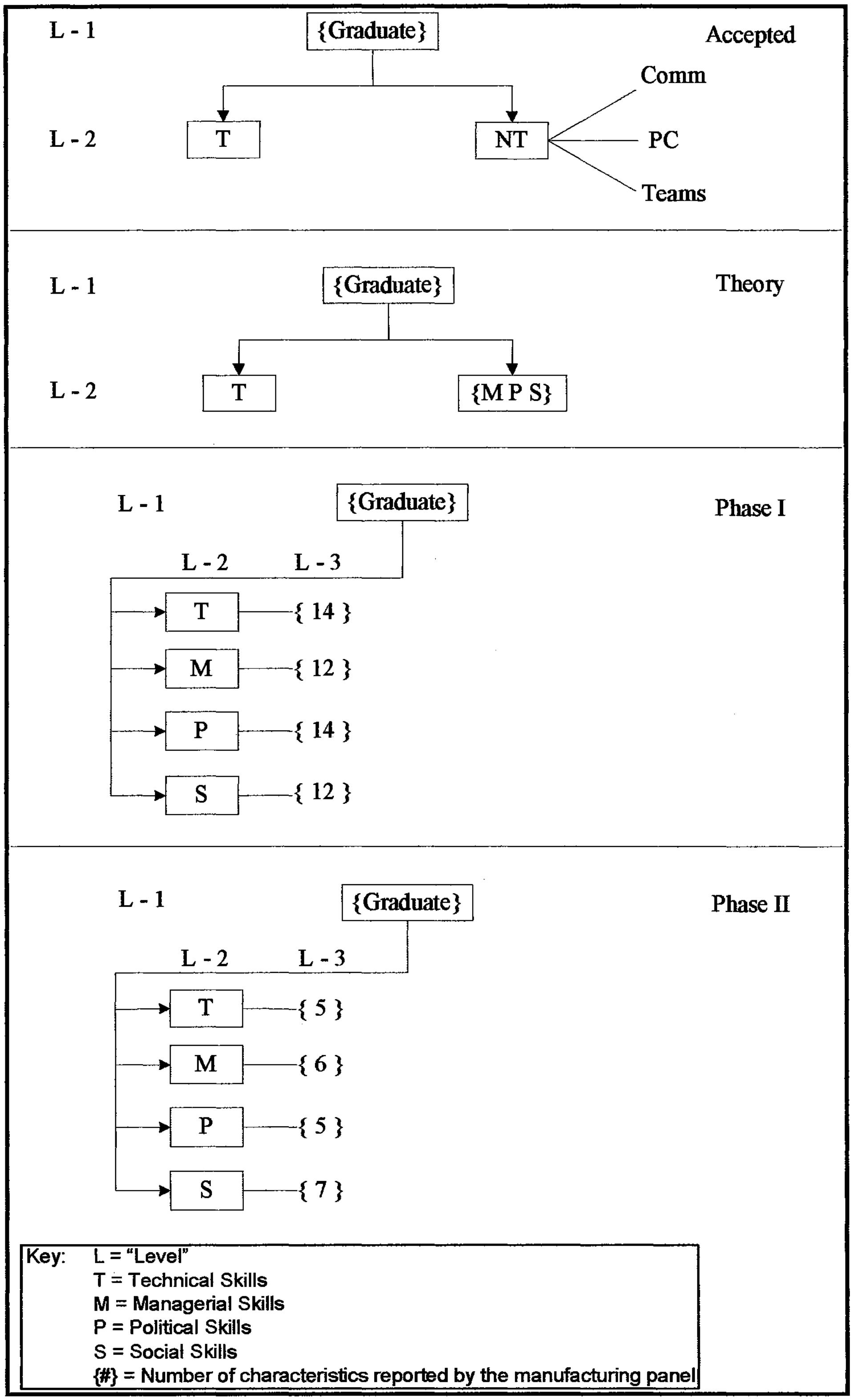


Figure 4.4 AHP Models: "Accepted", Theory, and Phases I and II

Phase II concluded with four primary characteristics and 23 sub-characteristics unequally distributed among their parent characteristics. That is, a consensus of the participants' verbal contributions and subsequent clarifications, and combinations may not have been equally distributed following the NGT session's round-robin phase. Further, the following steps were completed in the research methodology:

- Step 4: Develop an AHP hierarchy. This was accomplished.
- Step 5: Develop a research instrument based upon the AHP hierarchy. This step was accomplished.
- Step 6: Pretest the research instrument. This step was accomplished.

4.6 Phase III

In this phase, the instrument (Appendix 9) was distributed, the data analyzed [see Sections 4.7 and 4.8], and hypotheses made [See Section 4.9]. An example of this refined survey is shown with a copy of the instruction sheet below.

******* INSTRUCTIONS *******

ANALYTICAL HIERARCHY PROCESS

PAIRED COMPARISON INSTRUMENT

For each paired comparison, please circle the Factor (Factor A or Factor B) that is more important in the selection of the ideal graduate engineering candidate. A definition of each Primary (Level 1) and Secondary (Level 2) Factor is provided. If both factors are equally important, then circle both. Evaluate the most important factor by circling the degree of importance or preference using the nine-point scale below:

If the factor is:	the rating to assign is
Equally important or preferred	**1**
Weakly important or preferred	**3**
Strongly important or preferred	**5**
Very strongly important or preferred	**7**
Absolutely important or preferred	**9**

Please note that even numbers (2, 4, 6, 8) may be considered compromises between the preference ratings.
You may document your rationale for your preferences in the space provided.

PRIMARY FACTORS "A"	"B"	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
Technical	Managerial	1	2	3	4	5	6	7	8	9	
Technical	Political	1	2	3	4	5	6	7	8	9	
Technical	Social	1	2	3	4	5	6	7	8	9	
Managerial	Political	1	2	3	4	5	6	7	8	9	
Managerial	Social	1	2	3	4	5	6	7	8	9	
Political	Social	1	2	3	4	5	6	7	8	9	

To motivate a higher response, the author used the United States Postal System's (USPS) 2-Day Priority, with enclosed pre-paid and addressed USPS 2-Day Priority return envelopes to send the expert stakeholder sample populations of academicians and manufacturers (Warde, 1990). The students (undergraduate and graduate) were asked to participate in class without the author present. Figure 4.5 shows Phase III with inbound connector "2 Out" from Phase II and outbound connector "3 Out" connecting it to "Output" analyses stage shown in Figure 4.6.

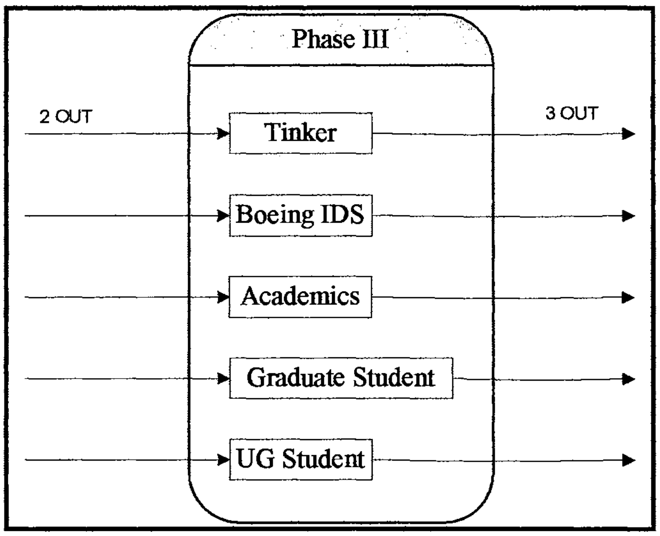


Figure 4.5 Research Phase III Model

Data received during this phase is reported as follows: a total of 20 academic surveys mailed (10 returned, 8 usable, 1 returned but no reply received, 1 not used due to presumed bias (based on their excoriating critical comments made on the cover sheet and potentially biased responses), and two "promised", but no replies received; 21 manufacturing surveys mailed: 10 at the Oklahoma City Air Logistics Center and 11 at Boeing IDS (14 returned, 12 usable, 2 returned for clarification with no reply for either survey. Follow-up letters did not motivate replies); and 29 student surveys presented in classroom setting: 18 MSIE and 11 undergraduate, senior-classified BSIE (all returned, all complete, and all usable). Telephonic contact was not made to non-responders at the request of Dr. Wayne Jones and Mr. John Crutchfield, the primary points-of-contact at the Oklahoma City Air Logistics Center and Boeing IDS, respectively.

Figure 4.6 shows the sets of weighted judgments from Phase III as "3 Out" process arrows entering the analyses portion of the research.

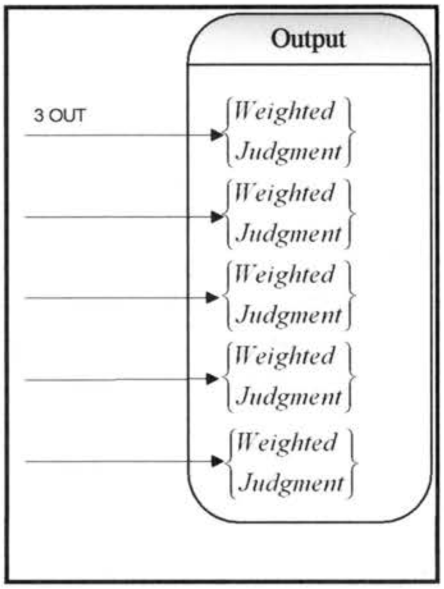


Figure 4.6 Research Phase III Output Model

All participants were given the proper "Volunteer to Participate" letters. Data as returned was entered by the author with clerical assistance into a Microsoft Excel© spreadsheet and Expert Choice 2000© database. Periodic quality control of the data was enabled by the enumerator [author] reading back the entered data to the clerk to verify correctness [selected characteristic is correct and the strength of the priority is correct]. In cases where the respondent failed to select the characteristics, but did select the priorities, their submission was set-aside for later return and clarification. In those cases, subsequent telephone calls (academician only), e-mails (to "all"), or first-class letters (manufacturers only) alerted the respondent that they are requested to re-accomplish all or part of the instrument. In those cases where the author and the clerk observed missing or inconsistent data exceeding a pre-set threshold, returns of surveys to the participants occurred in 3 of the 53 completed instruments. None of the three were resubmitted, however.

4.7 The Data

As previously stated, the primary data are the results of a mailed survey instrument distributed to a research frame of manufacturing respondents assigned to the Oklahoma City Air Logistics Center or to

Boeing Integrated Defense Systems, Saint Louis, Missouri. Additionally, the primary data are the results of a mailed survey instrument distributed to a research frame of faculty respondents representing Industrial Engineering departments located in Oklahoma , Arkansas, Missouri, Texas, Kansas, and New Mexico. A frame of undergraduate and graduate industrial engineering students was selected by convenience from a graduate-level course the author taught in Industrial Engineering Organizational Systems at a school of industrial engineering located at a Midwestern research institution of higher education. All potential respondents were allowed the opportunity to volunteer and to sign a statement to that effect (Appendix 9). See Appendix 1 for a copy of the Oklahoma State University, Institutional Review Board Letter of Approval to conduct research using human subjects. All potential participants were screened by reference to the definitions of "expert" and "student" [See Section 1.5, "List of Definitions."]

4.7.1 Analytical Hierarchy Process

The remaining sections in Section 4.7 explain the use of AHP in the research. It follows from the introduction to AHP given in Chapter 2, Section 2.17.3.

4.7.2 The Analytical Hierarchy Process Explained

The following example illustrates the methodology used in the analytical hierarchy process. It illustrates the fundamental process underlying the Expert Choice® [EC2000] application software employed in the research and uses empirical data extracted from one research respondent's judgments.

4.7.2.1 Method.

A matrix of judgments is made from a respondent's pairwise comparisons of characteristics of the ideal engineer (See Table 4.5). In this example, the judgments of a manufacturing stakeholder respondent are illustrated. As such, the respondent is comparing the characteristics of *technical, managerial, social,* and *political* [level 2 characteristics] to themselves to determine their relative impact, priority, upon the next higher level in the hierarchy. It is a square matrix with as many rows and columns as there are characteristics connected to the goal. The matrix principal diagonal is "1" reflecting the identity of comparing a characteristic to itself. That is, comparing "M" to "M", *management* to *management,* it is logical that an equal preference results. Further, the matrix is symmetrical about the principal axis, because reciprocity about the principal axis is assumed as AHP uses the ratio scale. That is, the integer values show preference of one characteristic over the characteristic to which it is compared and fractional values reflect an inverse relationship, $a_{ij} = 1/ a_{ij}$, preference for the value to which the characteristic is compared. For example, comparing characteristic "M" to "T", *management* to *technical*, [row 2 and column 1] we see a preference of "M" to "T" of 3; the reciprocal comparison is shown as 1/3 or 0.333+ converted to its decimal equivalent. Other pairwise judgments follow as shown, where, "M" and "T" are as previously defined and "P" is the *political* characteristic and "S" is the *social* characteristic:

Table 4.5 Judgment Matrix [Empirical Research Data]

Skills and Knowledge	**T**	**M**	**P**	**S**
T	1.000	0.333	3.000	0.200
M	3.000	1.000	5.000	0.333
P	0.333	0.200	1.000	0.143
S	5.000	3.000	7.000	1.000

Following the construction of the matrix of pairwise comparison, the vector of priorities from the given matrix is developed. First, the original judgment matrix is normalized using the sum of each column and then the rows are divided by the number of judgments per row. Saaty (1988) suggests that crude estimates of the priority vector are "good", using this procedure. Table 4.6 shows that computed matrix and Table 4.7 shows the simple average as the "Priority Vector". Both tables were computed using Microsoft Excel® XP

Table 4.6 Normalized Judgment Matrix [Empirical Research data]

Skills and Knowledge	**T**	**M**	**P**	**S**
T	0.1071	0.0735	0.1875	0.1193
M	0.3214	0.2206	0.3125	0.1989
P	0.0357	0.0441	0.0625	0.0852
S	0.5357	0.6618	0.4375	0.5966

Table 4.7 Normalized Judgment Matrix with its Simple Average Priority Vector [Empirical Research Data]

Skills and Knowledge	T	M	P	S	Priority Vector: Simple Average
T	0.1071	0.0735	0.1875	0.1193	0.1219
M	0.3214	0.2206	0.3125	0.1989	0.2633
P	0.0357	0.0441	0.0625	0.0852	0.0569
S	0.5357	0.6618	0.4375	0.5966	0.5579

Saaty (1985) reports the use of three other algorithms, all of which are judged equal to or less optimal than is this method of averaging over the normalized columns. One of these three will be used in this research due to its use in EC2000 application software and that the priority averages are approximately equal to a simple average, previously discussed.

As previously discussed, an alternative procedure is given by Saaty (1985) that computes the geometric mean for each row. This procedure is approximately equal in precision to the row averages of the normalized rows. However, it is advantageous when inconsistency in the judgments is present (Saaty 1985). However, the author found no research into the sensitivity of the latter procedure over the method of a simple average over the normalized columns.

If we compute the priority vector using the geometric mean, then the matrix in Table 4.8 results:

Table 4.8 Normalized Judgment Matrix with its Priority Vector: Simple and Geometric [Empirical Research Data]

					Priority Vector	
Skills and Knowledge	T	M	P	S	simple average	geometric average
T	0.1071	0.0735	0.1875	0.1193	0.1219	0.1165
M	0.3214	0.2206	0.3125	0.1989	0.2633	0.2588
P	0.0357	0.0441	0.0625	0.0852	0.0569	0.0544
S	0.5357	0.6618	0.4375	0.5966	0.5579	0.5528

Expert Choice® employs the geometric mean procedure to calculate the priority vector.

The formula to calculate the geometric mean is:

$$\text{Geometric Mean: } J_g\left(k,l,m,n\right)=\prod_{i=1}^{n} J_i\left(k,l,m,n\right)\text{, where}$$

$J_g\left(k,l,m,n\right)=$ the group judgment of the relative importance of characteristics k, l, m, and n,

$J_i\left(k,l,m,n\right)=$ the individual judgment of the relative importance of characteristics k, l, m, and n,

k, l, m, and *n* = the Level 2 characteristics of *technical, managerial, social,* and *political* attributes

Following the first computation of the priority vector, EC2000® raises the normalized matrix [and successive matrices] to successively higher powers. At each step, the resultant column vector of priorities is compared with the preceding vector. The process ends, when the absolute difference between the vectors approximates zero. This complexity is reduced by using the Expert Choice® software. Further, the accuracy of the final priority column vector is improved as Saaty suggests for inconsistent judgments (Saaty, 1998). However, as discussed, the precise level of inconsistency or the presence of any inconsistency is not given beyond which one method over another is suggested.

4.7.2.2 Determining the Consistency Ratio.

To determine the consistency ratio, we must compute the weighted sum vector $\vec{\lambda}$ and the consistency vector. The weighted sum vector is found by multiplying the original pairwise comparison matrix [See Table 4.9] by the column priority vector. The following matrix results:

Table 4.9 Weighted Sum Vector Data [Empirical Research Data]

Skills and Knowledge	**T(0.117)**	**M (0.259)**	**P (0.054)**	**S (0.55)**	$\vec{\lambda}$	$\vec{\lambda}$ **max**
T	1.000	0.333	3.000	0.200	4.062678	4.117089
M	3.000	1.000	5.000	0.333	4.105534	
P	0.333	0.200	1.000	0.143	4.136508	
S	5.000	3.000	7.000	1.000	4.163636	

In the preceding table, the column titled λ is calculated by multiplying the original matrix of judgments by the column priority vector and then summing each row. $\vec{\lambda}$ **max** is calculated by dividing each row sum by the priority column vector and averaging the resultant values.

We then compute the consistency index (CI) as follows:

$CI = \frac{\vec{\lambda}_{max} - n}{n-1}$, where n is the number of judgments. Therefore, in the actual data shown,

$CI = \frac{4.1171 - 4}{4-1} = 0.039$. Next the consistency ratio (CR) is computed as the ratio of the consistency index divided by the random index. The random index (RI) is a value given in Table 10 showing random indices defined by Saaty (1988) as calculated by Foreman:

Table 4.10 Random Index Table of Values

n	2	3	4	5	6	7	8
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41

Where n = order of the matrix.

Therefore, for the given example, $CR = \frac{0.039}{0.90} = 0.043$. This consistency is "acceptable" (Saaty, 1986).

4.8 A Summary of the Methods to Answer the Sub-objectives of the Research

The research Phases I, II, and III were planned to answer the sub-objectives:

<u>Sub-objective 1</u>. *Develop a methodology from which to understand the needs of a stakeholder in the industrial engineering graduate student. Understand the process of obtaining a consensus of opinion from a consuming stakeholder and select a "best" method. Compare, understand and select a "best" comparative weighting scheme.*

The following methodological steps were used:

(1) Conducted interviews with manufacturing and academic experts to understand one sample of the required characteristics of graduate-level engineers presenting themselves for employment [See Chapter 2, Section 2.16.4].

(2) Conducted a literature review using a form of Porter's (1985) "value-added" model. [See Chapter 2, Figure 2.1].

(3) Planned the research using the AHP method for making qualitative comparisons between the required characteristics of graduate-level engineers presenting themselves for employment [See Tables 3.1 and 4.1].

(4) Conducted a Nominal Group Technique and Affinity Grouping session with the manufacturer [See Section 4.3].

(5) Built surveys using an iterative building process with manufacturing and academic experts [See Section 4.5].

<u>Sub-objective 2</u>. *Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes. A demand-pull process should clearly understand the skills and knowledge requirements, the hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.*

The following methodological steps used primary and secondary data.

(1) Interviewed practicing manufacturing experts [See Sections 4.3.2., 4.4].

(2) Developed a skills hierarchy for manufacturing industrial engineers [See Section 4.3.4].

(3) Conducted a sample of manufacturing companies[See Section 4.6]

(4) Analyzed comparative judgments using analytical hierarchy processes [See Chapter 5].

<u>Sub-objective 3</u>. *Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes. The demand-pull process should have the academicians understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationships among the requirements, and the weights [priorities] given these skills and knowledge.*

(1) Conducted a sample of expert academically assigned industrial engineers [See Section 4.6].

(2) Analyzed comparative judgments using tests of statistical significance [See Chapter 5].

<u>Sub-objective 4</u>. *Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes. The demand-*

pull process should have the students understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

The following methodological steps used primary and secondary data.

(1) Conducted a sample of senior and graduate-level industrial engineers [See Section 4.6].

(2) Analyzed comparative judgments using analytical hierarchy processes [See Chapter 5].

Sub-objective 5. *Determine the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through analyzing and comparing the similarity of their individual priorities.*

The following methodological steps used primary and secondary data.

(1) Completed a statistical analysis using the variables previously described [See Chapter 5].

4.9 Statement of the Hypotheses

Figure 1.1 presented the triangular model for testing the agreement between the stakeholders on the goal *"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"* Chapter 2 built upon this model in presenting the literature search model, Figure 2.1.

As initially stated in Chapter 4, section 4.3.2, the NGT and Affinitization process was built to approach an answer to that goal. The surveys in Phase III tested the strength of the judgments between the respondents' samples on that goal. Figure 4.7 maps the sub-objectives to the triangular approach to the goal. Table 4.3 maps the hypotheses to the sub-objectives.

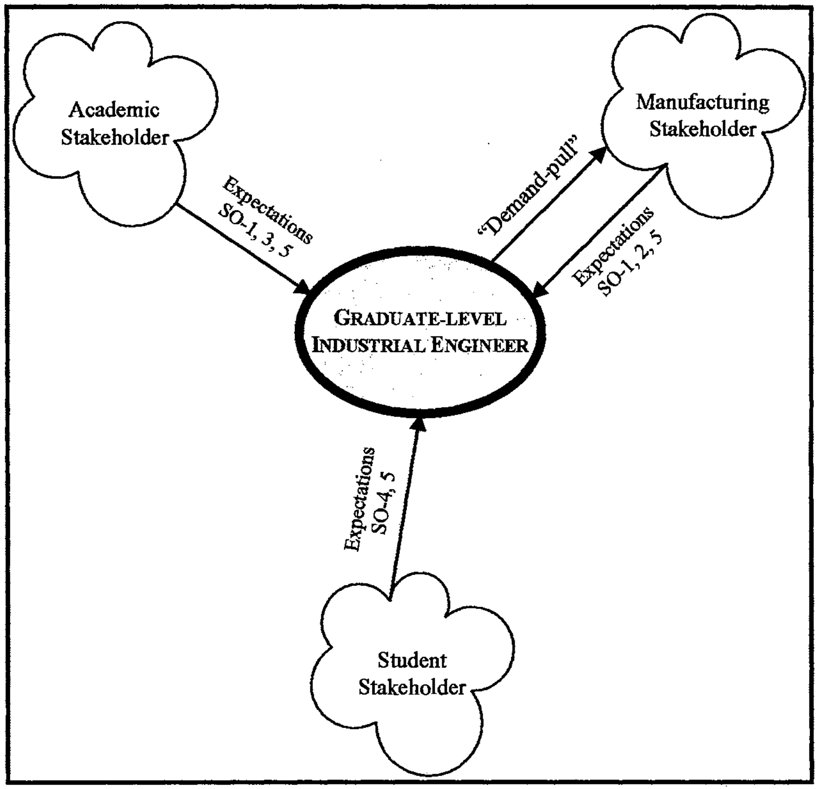


Figure 4.7 Triangular Perspectives of the "Stakeholder" Populations with Sub-objectives

As a result, the hypothesis is that,

> *There is alignment between the academia, student, and employer goals for the characteristics of the graduate-level industrial engineering candidate.*

Table 4.9 summarizes the hypotheses shown in text form in Sections 4.9.1 through 4.9.6.4.

Table 4.11 Summary of Hypotheses

Hypothesis	Null Hypothesis	Alternative Hypothesis	Population & Characteristic tested	Sub-objectives Researched
1	H_0:	H_1:	Academic and Manufacturing judgments for characteristics -	2,3
1.1	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	T	
1.2	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	M	
1.3	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	S	
1.4	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	P	
2	H_0:	H_1:	Academic and Graduate Student judgments for characteristics -	2, 4
2.1	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	T	
2.2	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	M	
2.3	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	S	
2.4	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	P	
3	H_0	H_1:	Academic and Under Graduate Student judgments for characteristics -	2,4
3.1	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	T	
3.2	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	M	
3.3	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	S	
3.4	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	P	
4	H_0:	H_1:	Manufacturing and Graduate Student judgments for characteristics -	1,4
4.1	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	T	
4.2	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	M	
4.3	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	S	
4.4	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	P	
5	H_0:	H_1:	Manufacturing and Under Graduate Student judgments for characteristics -	1,4
5.1	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	T	
5.2	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	M	
5.3	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	S	
5.4	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	P	
6	H_0:	H_1:	Graduate Student and Under Graduate Student judgments for characteristics -	4
6.1	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	T	
6.2	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	M	
6.3	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	S	
6.4	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	P	

T = Technical; M = Managerial; S = Social; P = Political; H_0 & H_1: are the hypotheses; and μ = population mean.

Sections 4.9.1 through 4.9.6.4 state the hypotheses to be tested. In each case the null hypothesis is stated. The alternate hypothesis is implicit in all hypotheses, but expressed in Hypothesis 1.0 for illustrative purposes.

4.9.1 Hypothesis 1.0

Null hypothesis: There is alignment between industrial engineering academic and employer goals for the characteristics of the graduate-level industrial engineering candidate

Versus

Alternate hypothesis: There is at least one misalignment between industrial engineering academic and employer goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.1.1 Hypothesis 1.1

There is alignment between industrial engineering academic and employer goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.1.2 Hypothesis 1.2

There is alignment between industrial engineering academic and employer goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.1.3 Hypothesis 1.3

There is alignment between industrial engineering academic and employer goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.1.4 Hypothesis 1.4

There is alignment between industrial engineering academic and employer goals for the political characteristic of the graduate-level industrial engineering candidate.

4.9.2 Hypothesis 2. 0

There is alignment between industrial engineering academic and graduate student goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.2.1 Hypothesis 2.1

There is alignment between industrial engineering academic and graduate student goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.2.2 Hypothesis 2.2

There is alignment between industrial engineering academic and graduate student goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.2.3 Hypothesis 2.3

There is alignment between industrial engineering academic and graduate student goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.2.4 Hypothesis 2.4

There is alignment between industrial engineering academic and graduate student goals for the political characteristic of the graduate-level industrial engineering candidate.

4.9.3 Hypothesis 3. 0

There is alignment between industrial engineering academic and undergraduate student goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.3.1 Hypothesis 3.1

There is alignment between industrial engineering academic and undergraduate student goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.3.2 Hypothesis 3.2

There is alignment between industrial engineering academic and undergraduate student goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.3.3 Hypothesis 3.3

There is alignment between industrial engineering academic and undergraduate student goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.3.4 Hypothesis 3.4

There is alignment between industrial engineering academic and undergraduate student goals for the political characteristic of the graduate-level industrial engineering candidate.

4.9.4 Hypothesis 4.0

There is alignment between industrial engineering academic and employer goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.4.1 Hypothesis 4.1

There is alignment between employer and graduate student goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.4.2 Hypothesis 4.2

There is alignment between employer and graduate student goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.4.3 Hypothesis 4.3

There is alignment between employer and graduate student goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.4.4 Hypothesis 4.4

There is alignment between employer and graduate student goals for the political characteristic of the graduate-level industrial engineering candidate.

4.9.5 Hypothesis 5. 0

There is alignment between the manufacturing and undergraduate student goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.5.1 Hypothesis 5.1

There is alignment between the manufacturing and undergraduate student goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.5.2 Hypothesis 5.2

There is alignment between the manufacturing and undergraduate student goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.5.3 Hypothesis 5.3

There is alignment between the manufacturing and undergraduate student goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.5.4 Hypothesis 5.4

There is alignment between the manufacturing and undergraduate student goals for the political characteristic of the graduate-level industrial engineering candidate.

4.9.6 Hypothesis 6.0

There is alignment between the graduate student and undergraduate student goals for the characteristics of the graduate-level industrial engineering candidate.

4.9.6.1 Hypothesis 6.1

There is alignment between the graduate student and undergraduate student goals for the technical characteristic of the graduate-level industrial engineering candidate.

4.9.6.2 Hypothesis 6.2

There is alignment between the graduate student and undergraduate student goals for the managerial characteristic of the graduate-level industrial engineering candidate.

4.9.6.3 Hypothesis 6.3

There is alignment between the graduate student and undergraduate student goals for the social characteristic of the graduate-level industrial engineering candidate.

4.9.6.4 Hypothesis 6.4

There is alignment between the graduate student and undergraduate student goals for the political characteristic of the graduate-level industrial engineering candidate

4.10 Assumptions and Limitations

The following assumptions and limitations frame the research project.

- Research in the potential "users" of industrial engineers (I.E.'s) was limited to one of the largest manufacturer's and employers in the State of Oklahoma (Oklahoma City Air Logistics Center) and one of this industrial manufacturer's largest commercial suppliers. (See also Chapter 1.5, List of Definitions, *Expert panel – manufacturing*)
- Research into the "consumer" of I.E. education was limited to an opportunistically selected sample of industrial engineering students of one graduate-level I.E. academic class in the State of Oklahoma. (See also Chapter 1.5, List of Definitions, *Student*)
- Research in the potential I.E. academicians was limited to scholars assigned to industrial engineering departments in the State of Oklahoma and in states contiguous to Oklahoma. (See also Chapter 1.5, List of Definitions, *Expert panel – academic*)
- The research plan required that the "commercial" supplier to be demographically similar to the United States Air Force manufacturer for the assigned I.E. population.
- The number of AHP pairwise comparisons was reduced by respondent consensus from the original larger set to improve the response rate in follow-on research phases and to reduce the potential for internal inconsistency of judgments.
- Industrial engineering departments have advisory boards with representatives or representation from within and without the municipal locality in which the department is situated.
- A paucity of responses may limit the generalizability of the research.
- A paucity of responses may significantly influence the inconsistency index.
- The primary goal of this research is methodological.
- There are other stakeholders who may be interested in the alignment of engineering programs beyond those tested.
- Laurine (1997) discusses inherent limitations associated with the AHP due to its reliance upon the intuition and expertise of the managers. As Saaty (1994) says, "Decision makers are busy people."
- The aggregated cost to conduct the survey research became very expensive due to the instruments' preparation, reproduction, and postage expenses

4.11 Conclusions

This chapter discussed the application of the methodology introduced in Chapter 3 [See Table 3.1], a specific use of the research plan in three stakeholder population samples [See Table 4.1], the data secured for the research [See Sections 4.6 and 4.7], and the data's admissibility. Models for presenting this Chapter were given, Figure 4.7. The hypotheses that were tested are given in Table 4.3. Chapter 4 developed an approach to answering the research problem:

> *Determine a methodology or sequential approach for measuring the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers skills meeting the requirements of a selected stakeholders.*

Chapter 5. Application Results and Analyses

5.1 Introduction

The objective of this research project was to:

Determine a methodology or sequential approach for measuring the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers skills meeting the requirements of a selected stakeholders.

The hypotheses presented in Section 4.9 and the research objective and sub-objectives presented in Sections 1.4 and 4.8 require the analyses of the comparative judgments made by the participant populations on the following question *"[w]hat characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"* This question motivated the responses given in Phases I and II of the research, which, in turn, structured the hierarchy of characteristics of the graduate-level industrial engineering student presenting themselves for employing stakeholder following graduation. In this research, the demand-pull characteristics were framed by a manufacturing stakeholder – the Oklahoma City Air Logistics Center and Boeing Integrated Defense Systems- St. Louis site.

The purpose of this chapter is to present the results of the research and to analyze the data. The specific treatment of each sub-objective is also presented. Chapter 5 will initially discuss the results of the mailed survey. Then, the Chapter will present an analysis of the data.

The following lists the sub-objectives (SO #) and their descriptions analyzed in this Chapter [Please note that Sub-objective 1 was answered in Phases I, II, and III, see Chapter 4.5 and 4.6] :

- <u>Sub-objective 2</u>. *What are the priorities for skills and knowledge required in selected manufacturing companies?*
- <u>Sub-objective 3</u>. *What are the priorities for skills and knowledge in senior and graduate-level industrial engineers?*
- <u>Sub-objective 4</u>. *What are the priorities for skills and knowledge required in selected industrial engineering departments?*

- Sub-objective 5. *What are the differences between the priorities of a selected set of firms in the manufacturing industry, selected industrial engineering departments and the senior and graduate-level industrial engineers and are they significant?*

5.2 Survey results

The data were extracted from completed surveys and entered into a Microsoft Excel XP© spreadsheet for insertion into the Expert Choice 2000© (EC2000) application. Tables 5.2 through 5.6 report the results of the surveys. Each table is built similarly to the example shown in Table 5.1.

Table 5.1 "Respondent" Population Survey Results

	Global Priorities				
	Technical	**Managerial**	**Social**	**Political**	**C.I. Overall**
Obs.					
1	0.556	0.273	0.121	0.050	0.130
2	0.150	0.396	0.396	0.058	0.130
3	0.180	0.363	0.426	0.031	0.150
4	0.067	0.118	0.130	0.685	0.230
...	0.430	0.370	0.066	0.131	0.120
...	0.055	0.269	0.505	0.172	0.090
n	0.200	0.211	0.553	0.036	0.070
G.M.	0.146	0.282	0.200	0.127	0.099
Ideal	0.193	0.374	0.265	0.168	
Note:	G.M. = "Geometric Mean", Ideal = Normalized G.M, CI = Consistency Index, Obs. = Observation number.				

In Table 5.1, the example shows values in each column named "technical", "managerial", social", and "political". These terms refer to the characteristics judged by the survey participants and the values refer to the priority weight that this level 2 characteristic contributes to the goal. Recall from the discussion in Chapter 2, that Figure 2.2 presented a generalized AHP framework that was used in Phase III to structure the final AHP hierarchy for construction of the survey mailed to all participants [see Section 4.3.2 and Table 4.2]. In the above example, a geometric mean was used to obtain the group's judgment from the individual priorities given the characteristics "technical", "managerial", social", and "political" as Foreman and Peniwati (1998) state this to be the preferred parameter for judgments in which the individuals are considered as "one group" by the principle decision maker.

The formula to calculate the geometric mean is:

$$\text{Geometric Mean: } J_g(k,l,m,n) = \prod_{i=1}^{n} J_i(k,l,m,n), \text{ where}$$

$J_g(k,l,m,n) =$ the group judgment of the relative importance of characteristics k, l, m, and n,

$J_i(k,l,m,n) =$ the individual judgment of the relative importance of characteristics k, l, m, and n,

k, l, m, and *n* = the Level 2 characteristics of *technical, managerial, social,* and *political* attributes

The column named "C.I. Overall" is the consistency index for the individual decision maker for each observation. This is a value calculated by EC2000 using the relationship previously discussed in Chapter 2, Section 2.17.3 and with the table of random indexes shown in Table 4.10.

Summary of the data. Table 5.2 reports a summary of data collected from the participant populations. They provide support for answering sub-objectives 2, 3, 4, and 5.

Table 5.2 Global Priorities for Respondents

	Technical	**Managerial**	**Social**	**Political**
Academic	0.450	0.170	0.150	0.090
Manufacturer	0.315	0.218	0.307	0.057
Student-G	0.241	0.221	0.187	0.087
Student-UG	0.146	0.282	0.200	0.127
Geometric Mean	**0.266**	**0.219**	**0.204**	**0.087**
Normalized G.M.	0.34	0.28	0.26	0.11

The priorities given to the goal *"[w]hat characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"* That is, those skills meeting the requirements of a selected stakeholders are shown bolded in the row marked "Geometric Mean". A normalized set of geometric means is illustrated in row following these means.

Undergraduate student sample. Table 5.3 reports the results of surveying the undergraduate student population. It provides support for answering sub-objective 4.

Table 5.3 Undergraduate Student Sample Survey Results

	Global Priorities				
	Technical	**Managerial**	**Social**	**Political**	**C.I. Overall**
Obs.					
1	0.556	0.273	0.121	0.050	0.130
2	0.150	0.396	0.396	0.058	0.130
3	0.180	0.363	0.426	0.031	0.150
4	0.067	0.118	0.130	0.685	0.230
5	0.430	0.370	0.066	0.131	0.120
6	0.055	0.269	0.505	0.172	0.090
7	0.200	0.211	0.553	0.036	0.070
8	0.230	0.136	0.031	0.603	0.100
9	0.079	0.381	0.159	0.381	0.040
10	0.060	0.285	0.425	0.231	0.050
11	0.123	0.623	0.203	0.051	0.100
G.M.	0.146	0.282	0.200	0.127	0.099
Ideal	0.193	0.374	0.265	0.168	

Note: G.M. = "Geometric Mean",
Ideal = Normalized G.M,
CI = Consistency Index.

Graduate student participant sample. Table 5.4 reports the results of surveying the Graduate student population. It provides support for answering sub-objective 4.

Table 5.4 Graduate Student Sample Survey Results

	Global Priorities				
	Technical	**Managerial**	**Social**	**Political**	**C.I. Overall**
Obs.					
1	0.046	0.473	0.176	0.305	0.320
2	0.583	0.160	0.128	0.129	0.130
3	0.145	0.320	0.510	0.026	0.450
4	0.661	0.113	0.182	0.044	0.220
5	0.220	0.483	0.244	0.052	0.180
6	0.043	0.055	0.203	0.699	0.250
7	0.316	0.040	0.183	0.099	0.370
8	0.363	0.302	0.158	0.178	0.400
9	0.165	0.541	0.270	0.024	0.480
10	0.350	0.292	0.123	0.235	0.340
11	0.146	0.412	0.390	0.051	0.240
12	0.584	0.261	0.117	0.037	0.300
13	0.549	0.262	0.034	0.156	0.260
14	0.460	0.101	0.369	0.034	0.230
15	0.647	0.197	0.117	0.038	0.420
16	0.062	0.550	0.282	0.107	0.130
17	0.664	0.112	0.189	0.035	0.190
18	0.083	0.318	0.217	0.382	0.180
G.M.	0.241	0.221	0.187	0.087	0.263
Ideal	0.328	0.300	0.254	0.119	

Note: G.M. = "Geometric Mean",
Ideal = Normalized G.M,
CI = Consistency Index.

Manufacturing participant sample. Table 5.5 reports the results of surveying the manufacturing population. It provides support for answering sub-objective 4.

Table 5.5 Manufacturing Sample Survey Results

	Global Priorities				
	Technical	**Managerial**	**Social**	**Political**	**C.I. Overall**
Obs.	0.484	0.222	0.185	0.109	0.090
1	0.394	0.124	0.450	0.031	0.150
2	0.538	0.202	0.198	0.062	0.100
3	0.449	0.300	0.217	0.035	0.170
4	0.609	0.120	0.241	0.030	0.210
5	0.118	0.262	0.565	0.055	0.020
6	0.272	0.221	0.465	0.042	0.260
7	0.129	0.129	0.697	0.045	0.050
8	0.250	0.250	0.250	0.250	0.040
9	0.195	0.407	0.362	0.036	0.220
10	0.440	0.212	0.290	0.058	0.090
11	0.163	0.395	0.395	0.047	0.100
12	0.389	0.352	0.170	0.089	0.110
13	*	*	*	*	*
14	*	*	*	*	*
G.M.	0.300	0.228	0.313	0.056	0.101
Ideal	0.334	0.254	0.349	0.062	

Notes: (1) G.M. = "Geometric Mean"
(2) Ideal = Normalized G.M.
(3) " * " = a value not yet included or data recomputed following respondent's reconsideration of their initial vote.

Academic participant sample. Table 5.6 reports the results of surveying the manufacturing population. It provides support for answering sub-objective 4.

Table 5.6 Academic Sample Survey Results

	Global Priorities				
	Technical	**Managerial**	**Social**	**Political**	**C.I. Overall**
Obs.					
1	0.399	0.226	0.306	0.069	0.070
2	0.674	0.106	0.076	0.143	0.150
3	0.181	0.119	0.333	0.367	0.190
4	0.204	0.279	0.423	0.093	0.100
5	0.659	0.188	0.095	0.058	0.380
6	0.586	0.241	0.112	0.062	0.200
7	*	*	*	*	*
8	0.410	0.054	0.311	0.225	0.120
9	0.247	0.143	0.559	0.051	0.200
10	0.652	0.174	0.121	0.053	0.250
11	**0.679**	**0.218**	**0.025**	**0.078**	**0.240**
12	0.411	0.218	0.284	0.087	0.040
13	0.598	0.087	0.272	0.044	0.070
G.M.	0.432	0.156	0.183	0.088	0.141
Ideal	0.503	0.181	0.213	0.103	

Notes:
(1) G.M. = "Geometric Mean"
(2) Ideal = Normalized G.M.
(3) [box] = a value for which clarification is being sought with the respondent
(4) " * " = a value not included or data recomputed following respondent's reconsideration of their initial vote.
(5) = **Data changed subsequent to the initial analyses following a revised judgment survey by the respondent in reply to the researcher's request.**

5.2.1 Analyses of the Results

The sample data were visualized using Minitab, Version 13.0© and the DOTPLOT function. This was accomplished to "observe" the distribution of the observations prior to use of any statistical analysis tool that is sensitive to violations of underlying assumptions, i.e., the ANOVA procedure. First, normality was tested.

A dotplot of all observations given for the *technical, managerial, social,* and *political* characteristics is illustrated in Figure 5.1, which suggests very non-normally distributed data. Then a dotplot was constructed for each characteristic segregated by sample population (Figure 5.2), which reveals the source of the patterns in the observations.

However, as Toothaker (1991) states, "It is a very rare case when the actual data from a research project come from normal populations with equal variances and independent observations." As a result, further tests of normality and variance were warranted.

At this point in the research, based on Toothaker's assertions, the author elected to expand the research into further tests of normality and equal variance. The assumption of independence remained operative in the research for reasons already given in Chapters 3 and 4.

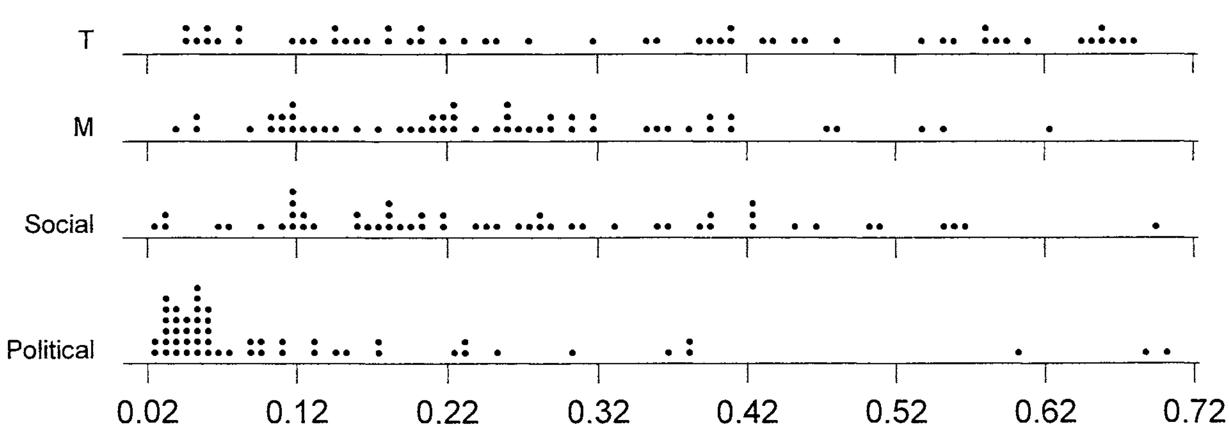


Figure 5.1 Dotplot of Sample Data for Technical, Managerial, Social and Political Characteristics

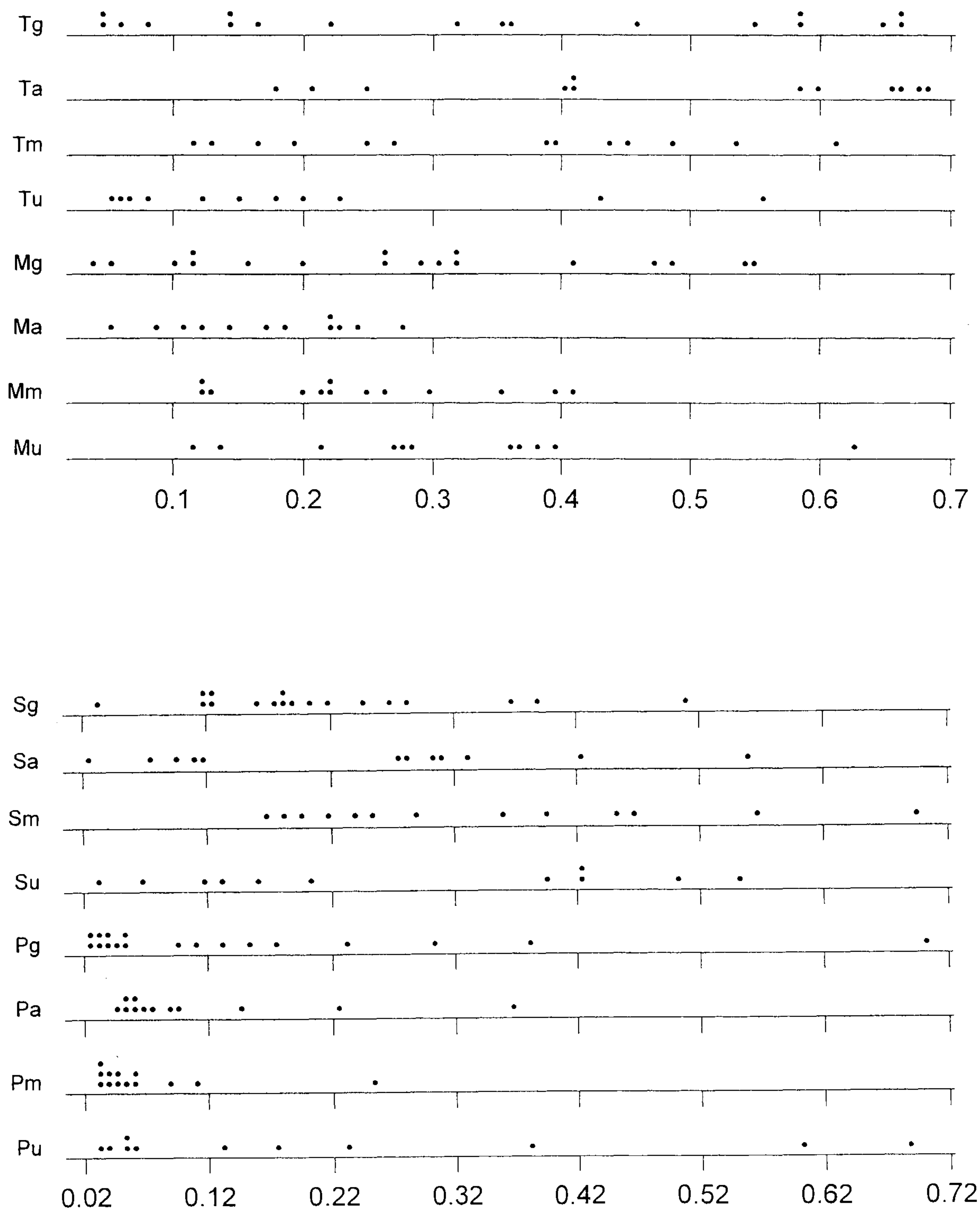


Figure 5.2 Grouped Dotplot of Sample Data

5.3 Univariate Tests of the Sampled Data.

Statistical tests of the data were conducted assuming univariate tests versus a multivariate approach, because the research sought to develop a method for assessing the significance of alignment between the *technical, managerial, social,* and *political* characteristics associated with academic, manufacturing, graduate and undergraduate research groups and where each characteristic is assumed mutually independent.

5.3.1 Methodology

Observations were taken from surveying the academician, manufacturer, graduate student, and undergraduate research student groups in their characteristics of technical, managerial, social, and political qualities, where the observation, $\{\chi_{i,j}\}$, i=1,…,4 {characteristic}; and j = 1,…,4 {group}. The data were initially evaluated in a univariate manner, assuming $X \sim N(0,1)$. The author initially assumed normality, independence, and equal variance in the distribution of the parent population represented by the sample data. This was done to assure robust (to Type 1 error) parametric tests could be employed in the analyses.

5.3.1.1 Independent t-Test

Given the apparent departures from normality, a further test of the data was conducted using a Microsoft® Excel XP-based macro to determine a "paired t-test statistic", assuming unequal variance. The independent t-Tests corroborated the SAS results and illustrated little difference between the groups for the four characteristics, previously discussed [See 2.1.1]

Table 5.7 Independent t-test of the Sample Data

	Error d.f.	t-Stat	t Critical two-tail	P(T<= t), two-tailed	Significant
At Mt	22	1.885211	2.079614	0.0727	
At Gt	24	1.560074	2.063898	0.1318	
At Ut	21	-3.825496	2.079614	0.0010	0.01
Mt Ut	21	2.212702	2.079614	0.0381	0.05
Mt Gt	29	0.036648	2.045231	0.9710	
Gt Ut	26	-1.969894	2.055531	0.0596	
Am Mm	22	-2.240878	2.073875	0.0355	0.05
Am Gm	25	-2.438823	2.059537	0.0222	0.05
Am Um	14	2.994627	2.144789	0.0097	0.01
Mm Um	17	-1.308252	2.109819	0.2082	
Mm Gm	28	-0.669800	2.048409	0.5085	
Gm Um	24	0.592683	2.063898	0.5589	
As Ms	23	-1.579499	2.068655	0.1279	
As Gs	19	0.501912	2.093025	0.6215	
As Us	20	0.423122	2.085962	0.6767	
Ms Us	20	0.975968	2.085962	0.3407	
Ms Gs	18	2.666130	2.100924	0.0157	
Gs Us	15	0.917341	2.131451	0.3735	
Ap Mp	18	1.324346	2.100924	0.2020	
Ap Gp	27	-0.719691	2.051829	0.4779	
Ap Up	13	1.446708	2.160368	0.1717	
Mp Up	11	-2.095353	2.200986	0.0601	
Mp Gp	22	-1.773750	2.073875	0.0899	
Gp Up	17	0.913700	2.109819	0.3737	

5.3.2 Non-Normality

As Osborne observes (2002), there are multiple ways for managing non-normal data. However, before any “change” in the observed data are explored, a researcher must conclude that the non-normality is either due to a valid reason (data are drawn from a non-normally distributed population) or an invalid reason (mistakes in data entry or missing data values not declared missing). To minimize a possibility of "invalid" data, the author insured accuracy by employing a technician to review all entries made personally by the author with corrections to tabled data and/or additions to missing entries immediately made to the data files. Other reasons for invalid data may be the presence of "outliers" (extreme observations) or the "nature of the variable", as Osborne asserts (2002). Statistical inference tests of outliers were considered, but discounted due to the paucity of observations and the reliance upon univariate tests of normality resultant from the SAS PROC UNIVARIATE PLOT NORMAL macros. Instead of tests for outliers, the author relied upon statistical tests, which are robust to "weighty tails" as discussed in Section 5.3.2.1. In regards to the data representing a non-normally distributed population, the paucity of survey participants made an assumption of normality suspect and a conservative approach is to assume a non-normally distributed population. However, to corroborate this approach, further tests of normality were pursued. Finally, the nature of the variable, personal opinions of the four research groups regarding implicit characteristics, may truly be non-normal (Osborne, 2002) as was assumed as such *post hoc* by the author.

Since the SAS PROC UNIVARIATE NORMAL macro "Tests for Normality" were remarkable in inferring the data are non-normally distributed [See the Box plots, Normal Probability plots, and reported statistics SAS routine as shown in Appendix 13, the author concluded that further analyses are needed to test for non-normality.

5.3.2.1 Goodness-of-Fit Tests for Statistical Distributions.

There are several quantitative "goodness-of-fit" tests of data, such as the Kolmogorov-Smirnov (K-S), chi-square, Shapiro-Wilk, Cramer-von Mises, and the Anderson-Darling (D'Agostino and Stephens, 1986). While there are also many non-parametric tests available, generally speaking, tests based upon a specific distribution are preferred, if they can be validated, over nonparametric tests because of their power and robust properties to type 1 and type 2 error, the conclusions are less vague.

It must be noted that these tests for normality do not state that the data were drawn from a normally distributed population. Rather, the tests state that the data make it unlikely that the population <u>is not</u> normally distributed (D'Agostino and Stephens, 1986). Of those goodness-of-fit tests listed, the Anderson-Darling is preferable for reasons to be now presented. Let's discuss the Anderson-Darling (A-D) test from its advantages and disadvantages.

An advantage of Anderson-Darling over other goodness-of-fit tests is that A-D may be used to determine if a sample is drawn from certain statistical distributions; among them are the exponential, Weibull, lognormal, and the normal. The A-D modifies the K-S to give additional weight to the tails of the data and assumes a specific distribution in contrast to the "distribution-free" K-S statistic. This characteristic allows for a more sensitive test (less chance of Type-II error). A-D is also preferred over chi-square if the sample is "small", as chi-square assumes that the sample size is "large enough" so the chi-square distribution is a good approximation of the test statistic (Conover, 1980). The author conservatively concluded that the research sample size was not "large enough." A-D tests ratio data, where chi-square is used in nominal data and K-S is employed in ordinal data. The present research data are ratio, because the participants provided relative judgments between the criteria defining each of the four characteristics in the AHP-based survey and the data exhibit "weight" in the tails (See Appendix 13). Therefore, a test of normality using a tool sensitive to the phenomenon of tail-weight is needed.

A disadvantage of A-D is that a critical statistic must be computed for each modeled distribution. In the present research, this required sixteen separate analyses (one for each of the four research groups (academician, manufacturer, graduate student, and undergraduate student) and their four characteristics (*technical*, *managerial*, *social*, and *political*). Another disadvantage for the A-D research tool is that tables of critical values of the A-D statistic are not in wide-spread publication and most researchers rely upon the computed statistics from statistical software. Further, most statistic programs do not adjust for small sample sizes.

As a result for the present research, the author drew a set of tabled values from those values reported in D'Agostino and Stephens (1986) and then adjusted as discussed below.

The Anderson-Darling test is as follows:

Table 5.8 Anderson-Darling Test

H_0:	The data follow a specific distribution.
H_1:	The data do not follow a specific distribution.
Test Statistic:	A-D test statistic is defined as $A^2 = -N - S$ where $S = \sum_{i=1}^{N} \frac{(2i-1)}{N}\left[\ln F(Y_i)\right] + \ln\left(1 - F(Y_{N+1-i})\right)$ and F is the cumulative distribution function of the specific distribution and Y_i are the ordered data.
Significance Level:	α
Critical Region:	(See discussion below)

The critical values for the A-D statistic depend upon the specific distribution under test. The test is a one-tail test with the null hypothesis that the distribution of the data is of the specific form under test and the alternative that it is not the specific distribution under test. Anderson-Darling found that the statistic may be multiplied by a constant to account for small sample size (D'Agostino and Stephens, 1986). Their conclusion was employed in this research to adjust the value of the A-D statistic from A^2 to A^* for comparison to $A^*_{critical}$, due to the small sample size as discussed in paragraph 2.6.3 below.

D'Agostino and Stephens (1986) report the A-D relationship for transforming A^2 to A^*. The equation is as follows:

$$A^* = A^2\left[1 + \frac{0.75}{n} + \frac{2.25}{n^2}\right]$$

A^* is then compared to a critical value from the Table 5.9 values of selected upper tail percentage points and the null hypothesis is then rejected, if A^* is greater than $A^*_{critical}$:

Table 5.9 D'Agostino and Stephens (1986) Tables

α	**0.1**	**0.05**	**0.025**	**0.01**
$A^*_{critical}$	0.631	0.752	0.873	1.035

An assumption was made (author) that the samples taken are described by the term "small" since the sample size *n* ranged from 11 to 18 observations as dependent upon the specific group being sampled that is *academician, manufacturer, graduate student,* or *undergraduate student.* As a result of making an assumption of a small sample, the A^* statistic was calculated and compared to $A^*_{critical}$.

5.3.2.2. Results of the Anderson-Darling Test.

The research hypotheses for the data are as follows:

Table 5.9.1 Research Test Using Anderson-Darling

H_0:	The data follow a Normal distribution, X ~ $N(0,1)$ for all $\{\chi_{i,j}\}$, where i=1,..., 4 {characteristic}; and j = 1,..., 4 {group}.
H_1:	The data do not follow a Normal distribution, X is not $N(0,1)$
Test Statistic:	A-D test statistic is defined as $A^2 = -N - S$ where $S = \sum_{i=1}^{N} \frac{(2i-1)}{N}[\ln F(Y_i)] + \ln(1 - F(Y_{N+1-i}))$ and F is the cumulative distribution function of the specific distribution and Y_i are "ordered data.
Significance Level:	$\alpha = 0.05$
Critical Region:	(See Table 5.8)

Test results for employing the A-D test are shown in Table 5.4.2.

Table 5.9.2 Anderson-Darling Statistic versus Power Statistic Test for Normality

Group	Characteristic	Sample size	P-Value	Calculated A2	Small Sample A2	Critical A2
Academic	Technical	12	0.076	0.630	0.679	0.752
	Managerial		0.747	0.231	0.249	
	Social		0.326	0.389	0.419	
	Political		<0.0001	1.507	**1.625**	
Manu.	Technical	13	0.508	0.313	0.335	0.752
	Managerial		0.440	0.339	0.363	
	Social		0.207	0.468	0.501	
	Political		<0.0001	1.781	**1.907**	
U-Grad.	Technical	11	0.021	0.830	**0.902**	0.752
	Managerial		0.403	0.350	0.380	
	Social		0.139	0.525	0.571	
	Political		0.010	0.946	**1.028**	
Graduate	Technical	18	0.071	0.658	0.690	0.752
	Managerial		0.455	0.341	0.358	
	Social		0.495	0.610	0.640	
	Political		<0.0001	1.751	**1.836**	
	total =	54				

In sum, the results indicate the following conclusions for the test subjects in this research:

Academic group. The null hypothesis [the data follow a Normal distribution] could not be rejected for the *technical, managerial,* and *social criteria. Technical, managerial,* and *social criteria* data exhibit normal distributions. However, the null hypothesis was rejected for the *political* criteria. *Political* criteria data do not exhibit normality characteristics.

Manufacturer's group. The null hypothesis [the data follow a Normal distribution] could not be rejected for the *technical, managerial,* and *social criteria.* However, the null hypothesis was rejected for the *political* criteria. *Political* criteria data do not exhibit normality characteristics.

Graduate student group. The null hypothesis [the data follow a Normal distribution] could not be rejected for the *technical, managerial,* and *social criteria.* However, the null hypothesis was rejected for the *political* criteria. *Political* criteria data do not exhibit normality characteristics.

Undergraduate student group. The null hypothesis [the data follow a Normal distribution] could not be rejected for the *managerial* and *social* criteria. However, the null hypothesis was rejected for the *technical* and *political* criteria. *Technical* and *political* criteria data do not exhibit normality characteristics.

5.3.2.3 Conclusion of Goodness of Fit Tests

As the A-D tests indicated only a moderate change from the conclusions made using the assumptions of normality, it may be concluded that while the assumption of normality may be suspect in all pairs of tests and could be rejected in favor of using statistical tests of significance relaxing an assumption of normality, the loss of power in pursuing these tests, non-parametric statistics for example, was not considered necessary by the researcher.

5.3.3 Unequal Variance Assumption.

The researcher was concerned with the performance of statistics used in the presence of a violation of the assumption of equal variance of the data. The presence of unequal variance had to be explored further in view of the variation in the individual and group decision consistency indexes, which may be indicative of inequality in the population variances. The survey data were entered the Minitab application and a test of equal variances was completed for all comparisons. In the test both Bartlett's F-test and Levene's test are reported. In Appendix 13, copies of the variance test are given. Minitab generates a plot that displays Bonferroni 95% confidence intervals for the population standard deviation at both factor levels. The graph also displays the side-by-side boxplots of the raw data for the two samples. Note that the 95% confidence level applies to the family of intervals and the asymmetry of the intervals is due to the skewness of the chi-square distribution. Table 5.9 presents the results of these tests. It reveals that the null hypothesis of equal variance could not be rejected in 19 of the 24 comparisons . This result suggests unequal variance is evident in the sample populations.

Table 5.10 Test of Equal Variances

	F-Test P Value		Levene's test P value			Significant	
At Mt	0.596		0.420				
At Gt	0.509		0.330				
At Ut	0.613		0.207				
Mt Ut	0.998		0.540				
Mt Gt	0.162		0.042			*	
Gt Ut	0.245		0.040			*	
Am Mm	0.285		0.439				
Am Gm	0.006		0.011			*	
Am Um	0.029		0.140				
Mm Um	0.216		0.386				
Mm Gm	0.065		0.054				
Gm Um	0.626		0.398				
As Ms	0.959		0.953				
As Gs	0.218		0.188				
As Us	0.590		0.396				
Ms Us	0.616		0.443				
Ms Gs	0.188		0.181				
Gs Us	0.070		0.031			*	
Ap Mp	0.117		0.416				
Ap Gp	0.050		0.274				
Ap Up	0.006		0.067				
Mp Up	0.000		0.017			*	
Mp Gp	0.001		0.089				
Gp Up	0.251		0.348				

Key:

Population: A=Academic; M=Manufacturer; G=Graduate Student; and U=Undergraduate Student

Characteristic t=technical; m=managerial; social; and p=political

5.4 Multiple Comparisons.

Since the research sought to make multiple comparisons and yet remain robust to Type 1 error, tests of multiple comparisons were explored that maintained "family-type relationships". Steele and Torrie (1980) discuss several multiple comparisons tests, which are Scheffe, Tukey, Student-Newman-Keuls, Duncan, and Waller-Duncan. However, an assumption of non-equality of variances cannot be violated. As such, a test was required that was robust to unequal population variances.

5.4.1 Games-Howell "multiple comparisons" procedure.

The Games-Howell "multiple comparisons" procedure provides the researcher with a "family-wise" statistic. As Steele and Torrie discuss, a "...true *experimentwise* error rate must clearly allow any and all hypotheses to be tested." They go on to state that, "Generally, it is desired to test only a subset or family of null hypotheses; the set of all possible paired comparisons is really a *family*, each treatment vs. control is really another,..., usually a single family is associated with any experiment." A *familywise* error rate is defined as the value approached by

$$\textit{Familywise}\text{ error rate } (H_0 \text{ true}) = \frac{\text{number of families with at least one erroneous inference}}{\text{number of families tested}}$$

Games-Howell proposed a procedure similar to those used by Welch (1949) and others dealing with the problem of unequal variances. Calculation of the statistic is as follows:

$$t_{jk} = \frac{\overline{Y} - \overline{Y}_k}{\sqrt{\dfrac{s_j^2}{n_j} + \dfrac{s_k^2}{n_k}}}$$ for each pair of means [in the research this equates to the means of the weighted judgments for the *technical, managerial, social,* and *political* criteria] $j \neq k$. The decision to reject the null hypothesis of equal variance if

$$\left|t_{jk}\right| \geq \frac{q^{\alpha}_{j,\mathrm{df}_{jk}}}{\sqrt{2}}$$ and otherwise fail to reject, where

$$\mathrm{df}_{jk} = \frac{\left(\frac{s_j^2}{n_j} + \frac{s_k^2}{n_k}\right)^2}{\left[\frac{1}{n_j - 1}\left(\frac{s_j^2}{n_j}\right)^2\right] + \left[\frac{1}{n_k - 1}\left(\frac{s_k^2}{n_k}\right)^2\right]}.$$ In this case an $\alpha =$ level critical value was used from a Studentized range table with the parameters j, df_{jk}. Games-Howell say that as a practical matter, to round off the df_{jk} to the nearest whole number to use as the critical value of the Studentized range. In this research, we conservatively rounded the df_{jk} to the next lowest whole number. This is to say that in the case where the calculated degrees of freedom result in a value between the tabularized integer values, the lower value for the error degrees of freedom was used.

It is evident from the data reported in Table 5.10 that in all comparisons with the exception of the *technical* characteristics between the academicians and undergraduate students and for the *managerial* characteristics between the academicians and undergraduate students, there is no statistical difference between the variances of the priorities in the sample data.

5.5 Conclusions

The survey of the sample populations presented data that departed from assumptions of normality and equal variance through statistical tests of the assumption of normality and equal variance. A familywise multiple comparisons test was selected that did not have an underlying assumption of equal variance between the sample populations. A test of the samples was then completed that revealed failure to reject the null hypotheses in two of the 24 comparisons: Academic and undergraduate student populations for the *technical* and *managerial* characteristics. Further, steps 10, 11, and 12 of the Research Plan [Table 4.1] were completed. Finally, Phase III of the research project was completed.

Table 5.11 Games-Howell Test Results

	Error d.f.	t-Stat	Games-Howell $\lvert t_{jk} \rvert$		Alpha 0.05	Alpha 0.01		Significant	
At Mt	22	1.885211	2.666091		3.96	5.02			
At Gt	24	1.560074	2.206278		3.90	4.91			
At Ut	21	-3.825496	-5.410068		3.96	5.02		**	0.01
Mt Ut	21	2.212702	3.129234		3.96	5.02			
Mt Gt	29	0.036648	0.051827		3.90	4.91			
Gt Ut	26	-1.969894	-2.785850		3.90	4.91			
Am Mm	22	-2.240878	-3.169080		3.96	5.02			
Am Gm	25	-2.438823	-3.449017		3.90	4.91			
Am Um	14	2.994627	4.235042		4.11	5.32		*	0.05
Mm Um	17	-1.308252	-1.850148		4.02	5.14			
Mm Gm	28	-0.669800	-0.947240		3.90	4.91			
Gm Um	24	0.592683	0.838181		3.90	4.91			
As Ms	23	-1.579499	-2.233749		3.96	5.02			
As Gs	19	0.501912	0.709810		3.98	5.05			
As Us	20	0.423122	0.598384		3.96	5.02			
Ms Us	20	0.975968	1.380227		3.96	5.02			
Ms Gs	18	2.666130	3.770477		4.00	5.09			
Gs Us	15	0.917341	1.297316		4.08	5.25			
Ap Mp	18	1.324346	1.872908		4.00	5.09			
Ap Gp	27	-0.719691	-1.017797		3.90	4.91			
Ap Up	13	1.446708	2.045954		4.11	5.40			
Mp Up	11	-2.095353	-2.963276		4.26	5.62			
Mp Gp	22	-1.773750	-2.508462		3.96	5.02			
Gp Up	17	0.913700	1.292166		4.02	5.14			

Key:

Population: A = Academic (n=12); M = Manufacturer (n=13); G = Graduate Student (n=18); and U = Undergraduate Student (n=11)

Characteristic t = technical; m = managerial; s = social; and p = political

Table 5.12 Summary of Hypotheses

Hypothesis	Null Hypothesis	Alternative Hypothesis	Population & Characteristic tested	Significant
1	H_0:	H_1:	Academic and Manufacturing judgments for characteristics -	
1.1	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	T	
1.2	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	M	
1.3	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	S	
1.4	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	P	
2	H_0:	H_1:	Academic and Graduate Student judgments for characteristics -	
2.1	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	T	
2.2	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	M	
2.3	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	S	
2.4	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	P	
3	H_0	H_1:	Academic and Under Graduate Student judgments for characteristics -	
3.1	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	T	** (0.01)
3.2	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	M	* (0.05)
3.3	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	S	
3.4	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	P	
4	H_0:	H_1:	Manufacturing and Graduate Student judgments for characteristics -	
4.1	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	T	
4.2	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	M	
4.3	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	S	
4.4	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	P	
5	H_0:	H_1:	Manufacturing and Under Graduate Student judgments for characteristics -	
5.1	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	T	
5.2	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	M	
5.3	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	S	
5.4	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	P	
6	H_0:	H_1:	Graduate Student and Under Graduate Student judgments for characteristics -	
6.1	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	T	
6.2	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	M	
6.3	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	S	
6.4	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	P	

T = Technical; M = Managerial; S = Social; P = Political; H_0 & H_1: are the hypotheses; and μ = population mean.

Chapter 6. Conclusions and Recommendations

6.1 Introduction

Chapter 6 argues for the conclusions derived from the experimental results, the contributions and limitations of the research, and the recommendations for future research.

6.2 Summary of Methods

The objective of the research project was as follows:

> *Model a methodology or sequential approach for measuring the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers' skills meeting the requirements of selected stakeholders.*

The research, then, had two foci: one – "…'modeling' an approach"; and two – "…'measuring' judgments" of research cohorts about a graduate-level industrial engineer.

The project was designed and executed using a method for conducting observational, descriptive survey research, because it was important to develop an understanding about the current status of goals alignment for a representative sample of stakeholders, who were drawn from three sources: expert panels of manufacturers and academicians, and from a classroom-based population of graduate-level and undergraduate-level industrial engineering students. The panels were comprised of industrial engineers meeting the researcher's definitions of "Expert Panel – Manufacturing" and "Expert Panel – Academics." The students met the researcher's definition of "student".

The methodology [or "sequential approach"] noted in the "Research Objective" modified algorithms previously tested by researchers using qualitative data in their projects (Leedy, 1993; Patton, 1980; and Fowler, 2002). Unique for this project, however, was a mapping of the Saaty (1985) methodology for using the AHP model to the researcher's model. Further, there were unique mappings of the research project's three major steps to the methodology [See Chapter 4 for discussion of Phases I, II, and III].

Stemming from the research objective were sub-objectives that were mapped to the research project's methodology model. The sub-objectives of the research project were as follows:

- **Sub-objective 1.** *Develop a methodology to understand the needs of a stakeholder in the industrial engineering graduate student and to understand the process of obtaining a consensus of opinion about their needs.*

- **Sub-objective 2.** *Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes.*

- **Sub-objective 3.** *Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes.*

- **Sub-objective 4.** *Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes.*

- **Sub-objective 5.** *Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.*

The methodology, then, was designed to model the research problem, the research objective, and to provide support for answering the questions noted in the sub-objectives. The methodology modeled a means to measure the judgments of and to understand the significance of the judgments made by the sample stakeholder populations.

The methodology provided focus on the needs of the customer of industrial engineering graduate-level students integrating multiple stakeholder perspectives, qualitative data, and group consensus tools. The nominal group technique and affinity diagramming processes were used in the expert panel – manufacturing to secure a group consensus of their needs in the industrial engineering graduate-level candidate seeking employment. From the hierarchically constructed set of manufacturer's consensus needs a process of developing a final set [of needs] proceeded through "Phases" [previously named Phase I, II, and III] and resulted in a qualitative survey distributed to other manufacturers, students, and academicians.

This methodology, then, is an integrated process of securing qualitative data for comparing the judgments of three distinct population samples of stakeholders in order to understand the level of alignment for the goal of the skills set required in the graduate-level industrial engineer.

Noted in Chapter 4.11, "Assumptions and Limitations", is the limitation of the sample populations to a convenience sample of students in the author's graduate-level academic course; an invited sample of manufacturing populations limited to two cohort populations; and academicians who were available during a non-academic period of the calendar year. While these samples are limiting in the statistical inference of the conclusions, the researcher contends that the samples are representative of their populations due to the expert character of the samples given in the researcher's definitions. That is, all sample subjects signed permission statements required by the Oklahoma State University Institution Review Board. Further, the Expert Panel – Manufacturing was selected by the senior engineer at each of the participating organizations. In addition, each participant was an industrial engineer and represented their respective engineering units that were comprised of a large number of engineers: industrial, mechanical, electrical, systems, aeronautical, and manufacturing.

6.3 Results and Conclusions

The methodology model (Figure 3.1, page 53) was employed. Twenty-four hypotheses were drawn (Table 4.11, page 97) representing a family of paired comparisons between the four sample populations [academic, manufacturing, graduate student, and undergraduate student] and the four characteristics: the *technical, managerial, social,* and *political.* The hypotheses were tested using the Games-Howell methodology in an MS Excel spreadsheet (Toothaker, 1991) with reported data illustrated in Tables 5.11 (page 123) and 6.1 (page 129), "Games-Howell Test Results," and Tables 5.12 (page 124) and 6.2 (page 130), "Summary of Hypotheses." These four tables summarize the statistical analyses detailed in Chapter 5, section 5.4.1.

The research could not find significant evidence to refute the hypotheses of no difference for the academic, manufacturing, and student populations between the *technical, managerial, social,* and *political* characteristics, except in two cases: the academic/*technical* and undergraduate student/*technical* and the academic/*managerial* and undergraduate student/*managerial.* It was unclear why there may be a difference in only two comparisons, given the lack of statistical significance for the other twenty-two comparisons, but this may be an area for future research: To further clarify the relationships between undergraduate and academic population opinion regarding graduate-level engineers in the *technical* and *managerial* characteristics, research the presence of confounding elements, and then retest for statistical significance.

As the data suggest, and the researcher concludes, that the research did not refute the majority of the hypotheses of no difference (Tables 5.12 and 6.2) and that a measure of "Statistical Alignment", as defined in Chapter 3, section 3.1.6 is shown. Alignment in this research was defined (Chapter 1, "Definitions", page 6) as a family-wise statistical comparison of the judgments of manufacturing companies to those judgments made by industrial engineering academia and industrial engineering students at the senior and graduate level. The precise level of alignment is not determined nor was this a sub-objective of the research.

It is, then, concluded that the manufacturing, academic and student sample populations are approximately coincident in their qualitative assessment of the needs for graduate-level industrial engineers.

6.3.1 The Sub-Objectives

The sub-objectives of the research are given in Tables 6.1, 6.2, 6.3 and 6.4. Table 6.3 uses the global weights to find a global geometric mean for all populations. Table 6.4 has the data in Table 6.3 normalized for a proportionate perspective. Future usage of these data is suggested in Section 6.6.

- **Sub-objective 2.** *Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes.*

  These priorities are given in Table 6.3 and 6.4 in the row, "Manufacturer".

- **Sub-objective 3.** *Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes.*

  These priorities are given in Table 6.3 and 6.4 in the rows, "Student-G" and "Student-UG" for graduate and undergraduate, respectively.

- **Sub-objective 4.** *Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes.*

  These priorities are given in Table 6.3 and 6.4 in the row, "Academic"

- **Sub-objective 5.** *Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.*

  This objective is answered below in Tables 6.1 and 6.2

Table 6.1 Games-Howell Test Results

	Error d.f.	t-Stat	Games-Howell $\lvert t_{jk} \rvert$	Alpha 0.05	Alpha 0.01	Significant	
At Mt	22	1.885211	2.666091	3.96	5.02		
At Gt	24	1.560074	2.206278	3.90	4.91		
At Ut	21	-3.825496	-5.410068	3.96	5.02	**	0.01
Mt Ut	21	2.212702	3.129234	3.96	5.02		
Mt Gt	29	0.036648	0.051827	3.90	4.91		
Gt Ut	26	-1.969894	-2.785850	3.90	4.91		
Am Mm	22	-2.240878	-3.169080	3.96	5.02		
Am Gm	25	-2.438823	-3.449017	3.90	4.91		
Am Um	14	2.994627	4.235042	4.11	5.32	*	0.05
Mm Um	17	-1.308252	-1.850148	4.02	5.14		
Mm Gm	28	-0.669800	-0.947240	3.90	4.91		
Gm Um	24	0.592683	0.838181	3.90	4.91		
As Ms	23	-1.579499	-2.233749	3.96	5.02		
As Gs	19	0.501912	0.709810	3.98	5.05		
As Us	20	0.423122	0.598384	3.96	5.02		
Ms Us	20	0.975968	1.380227	3.96	5.02		
Ms Gs	18	2.666130	3.770477	4.00	5.09		
Gs Us	15	0.917341	1.297316	4.08	5.25		
Ap Mp	18	1.324346	1.872908	4.00	5.09		
Ap Gp	27	-0.719691	-1.017797	3.90	4.91		
Ap Up	13	1.446708	2.045954	4.11	5.40		
Mp Up	11	-2.095353	-2.963276	4.26	5.62		
Mp Gp	22	-1.773750	-2.508462	3.96	5.02		
Gp Up	17	0.913700	1.292166	4.02	5.14		

Key:

Population: A = Academic (n=12); M = Manufacturer (n=13); G = Graduate Student (n=18); and U = Undergraduate Student (n=11)

Characteristic t = technical; m = managerial; s = social; and p = political

Table 6.2 Summary of Hypotheses

Hypothesis	Null Hypothesis	Alternative Hypothesis	Population & Characteristic tested	Significant
1	H_0:	H_1:	Academic and Manufacturing judgments for characteristics -	
1.1	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	T	
1.2	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	M	
1.3	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	S	
1.4	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	P	
2	H_0:	H_1:	Academic and Graduate Student judgments for characteristics -	
2.1	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	T	
2.2	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	M	
2.3	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	S	
2.4	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	P	
3	H_0	H_1:	Academic and Under Graduate Student judgments for characteristics -	
3.1	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	T	** (0.01)
3.2	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	M	* (0.05)
3.3	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	S	
3.4	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	P	
4	H_0:	H_1:	Manufacturing and Graduate Student judgments for characteristics -	
4.1	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	T	
4.2	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	M	
4.3	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	S	
4.4	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	P	
5	H_0:	H_1:	Manufacturing and Under Graduate Student judgments for characteristics -	
5.1	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	T	
5.2	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	M	
5.3	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	S	
5.4	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	P	
6	H_0:	H_1:	Graduate Student and Under Graduate Student judgments for characteristics -	
6.1	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	T	
6.2	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	M	
6.3	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	S	
6.4	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	P	

T = Technical; M = Managerial; S = Social; P = Political; H_0 & H_1: are the hypotheses; and μ = population mean.

Table 6.3 Global Priorities for Respondents: Non-normalized

	Technical	Managerial	Social	Political
Academic	0.432	0.170	0.150	0.090
Manufacturer	0.315	0.218	0.307	0.057
Student-G	0.241	0.221	0.187	0.087
Student-UG	0.146	0.282	0.200	0.127
Geometric Mean	0.263	0.219	0.204	0.087
Normalized G.M.	0.340	0.284	0.264	0.112

Population: Academic (n=12); Manufacturer (n=13); Student-G (Graduate) (n=18); and Student-U (Undergraduate) (n=11)

Table 6.4 Global Priorities for Respondents: Normalized

	Technical	Managerial	Social	Political	Σ
Academic	0.513	0.202	0.178	0.107	1.00
Manufacturer	0.351	0.243	0.342	0.064	1.00
Student-G	0.328	0.300	0.254	0.119	1.00
Student-UG	0.193	0.374	0.265	0.168	1.00
Geometric Mean	0.327	0.272	0.253	0.108	
Normalized G.M.	0.340	0.284	0.264	0.112	1.00

Population: Academic (n=12); Manufacturer (n=13); Student-G (Graduate) (n=18); and Student-U (Undergraduate) (n=11)

6.3.2 Research Concerns

The absence of a larger set of rejected null hypotheses is a concern. Primarily, this concern is based upon papers published by Wulf (1998), Galvin (1996), and Smerdon (1996) and a speech delivered by Feisel (1999) that, collectively, call for stronger ties between engineering colleges and the consuming stakeholders for a wide range of issues resulting from several contributing factors: globalization; changing patterns of employment; restructuring of the practice of engineering; new engineering methods; and new kinds of employers. Feisel (1999) states that these factors, at a minimum, "...have a direct impact on how engineering is structured and delivered." While none of the contributing factors were explicitly surveyed as part of the data collected in the research instrument, it is the author's opinion from the project's literature research (Chapter 2) and the demographic analysis of the manufacturers that these contributing factors

(Wulf, 1998; Galvin, 1996; Smerdon, 1996; and Feisel, 1999) are evident in the manufacturing population surveyed. Therefore, differences between the sample populations would have been expected.

Several conclusions are possible. The results may be biased by the respondent's ability to read and comprehend the survey. However, beyond the last names of the respondents, no demographic data was collected that sourced the English comprehension level [such as a TOEFL score, a.k.a. Test of English as a Foreign Language] for foreign-born faculty or undergraduate students. Also, definitions for all terms were given in the survey. Further, one of the academic expert panel members involved in pre-testing the survey was foreign-born and had no comments regarding the readability of the instrument. Another conclusion is that there is, in fact, a no significant difference between the survey populations and that the null hypotheses cannot be rejected of no differences between the characteristics of *technical, managerial, social,* and *political* in a graduate-level industrial engineer. As previously stated, this is an area for additional research.

6.4 Contributions

This research project has answered the research objective and provided models and data for continued research in the broad definition of the engineering discipline as well as quantitative components of the business higher education.

In attempting to satisfy institutional accreditation and the needs of various consuming stakeholders, university-level academic departments develop "linkage processes" to effect collaboration and cooperation with stakeholders (The Green Report: Engineering Education for a Changing World, 1994; Lang et al., 1999). However, author proposes that engineering linkages may be better understood with a model that gives a quantifiable measure of the technical and non-technical characteristics of an engineering graduate program's graduates.

This research project has added to the knowledge of the technical and non-technical components of a graduate-level industrial engineer's skills set. A systematic process to explicitly define a hierarchy of needs with dependencies and priorities spanning the technical and non-technical components of an industrial engineering program may now better understood by an academic program's stakeholders.

However, the research model is broadly structured to incorporate other engineering and non-engineering quantitative disciplines in traditional business areas. While the literature search failed to uncover similar research in engineering disciplines and the research focused exclusively upon the industrial engineer, the basic model is structured to be employed in a variety of disciplines and with the specific stakeholder populations to those disciplines.

A methodological approach for modeling the alignment of priorities in industrial engineering graduate-level degree holders was shown in a research project in an area that had not-to-date investigated a broad range of technical and non-technical characteristics requirements at the graduate level for manufacturers. That is, this research has demonstrated the use of stakeholder consensus in a demand-pull hierarchy built with consideration of the technical and non-technical requirements in the industrial engineering candidate holding the masters degree. Figure 1.1 "Triangular Perspectives of the 'Stakeholder Populations'" is a model that can be used to generalize to additional stakeholder perspectives about the graduate-level engineer. The research model (Chapter 3, Figure 3.1, page 53) can be used in a variety of stakeholder populations to test the model and to provoke judgments about their requirements in a graduate-level industrial engineer. As stated, while the literature search failed to uncover similar research in engineering disciplines and the research focused exclusively upon the industrial engineer, the basic model can be employed in a variety of disciplines and with the specific stakeholder populations to those disciplines to test its ability to discriminate qualitative judgments about characteristics essential to those discipline's graduates of graduate-level programs.

The research explicitly refines manufacturing expectations through an extensive iterative process and synthesizes a research instrument (Appendix 9) that has demonstrated applicability in a variety of engineering employment stakeholder populations. This survey instrument can be reviewed with other populations for interpretation and consensus on the definitions and, then, used in other engineering disciplines.

The literature search model (Chapter 2, Figure 2.1, page 12) can be used to explore other relationships in the "value-added" chain in manufacturing and service producing systems within and outside of engineering. For example, in 2001, the researcher completed IEM 5743, "Information Systems and Technology" at Oklahoma State University (Hartmann, 2001). In the course's semester project, he proposed comparative research into a firm's "web portals". Specifically, the proposal addressed the needs for the firm maintaining an electronic commerce presence on the Internet to have a quantifiable set of portal characteristics weighted by pairwise comparisons.

Finally, a summary set of priorities for *technical, managerial, social,* and *political* characteristics is shown. Extracted from Table 6.4, page 131 are the geometrically determined averages for all of the sample populations.

Normalized G.M.: Technical = 0.340; Managerial = 0.284; Social = 0.264; and Political = 0.112

As it was stated, that this research found statistical similarity for the industrial engineer's characteristics, then the proportion of weight given to the characteristics of *technical, managerial, social,* and *political* in a graduate-level industrial engineer are as shown above.

These results could have the potential to influence the expected outcomes of industrial engineering graduate-level students and programs, because engineering course objectives may need to be mapped to the proportion of the weight given them in the expectations of a manufacturing stakeholder as shown above. These weights are also significant for engineering higher education as they may be used to explore the relationships of programmatic outcomes to area objectives and to proportion the emphases in the technical and non-technical components of a graduate-level program.

6.5 Limitation of Research

The research was limited to the population of students currently available in the researcher's classroom. This may have bias inducing influence that despite attempts to assure anonymity and "no threat" bias did, in fact, result.

The research included a production value-chain cohort of manufacturing participants, although neither sample was made explicitly aware that the other was participating.

The number of participants was also limited. While it may have been more representative of manufacturers employing industrial engineers to open the survey to a larger population, the "problem" of determining a set of manufacturers with more than a small number of industrial engineers proved to be very difficult.

Faculty members approached to assist in the survey were selected on the basis of their currently serving as department chairs or have once served in that capacity.

A review of the research instrument should be accomplished with other stakeholder populations to determine their priorities and to broaden the applicability to additional engineering disciplines.

The postage expenses commensurate with the use of USPS Priority 2d day Delivery has shown greater than expected participation. Warde (1990) cites a less than 20% return on "unsolicited" surveys using "first class" and postage paid inserts. Perhaps, this research may append his data for current expedited mailing methods?

6.6 Recommendations

The implications for future research in this area are very intriguing. This research only begins to explore the demands of stakeholders for the characteristics of the graduate-level candidates they seek from the engineering schools of higher education.

The survey instrument can be reviewed and refined with additional expert engineering academic and manufacturing panels and the research model rerun in a variety of commercial and government-based product producing industries. Further, the process may be rerun in the service sector utilizing expert panels from that stakeholder community. Comparisons between the product and service producer, between the government and commercial product manufacturer and between engineering students from additional disciplines would be very interesting from the perspective of the proportion of weight given to the technical and non-technical components of the graduate-student's higher educational program.

Another area of research is to increase the number and type [product and service producing] of demand-pull stakeholders to the triangular model used (See Figures 1.1 and 4.7).

Further, the research has applicability in those areas of higher education more traditionally taught in the colleges of business. For example, the production and operations management and decision sciences disciplines have technical and non-technical components in graduate-level degree programs. It would appear that their graduates would have skills sets comprised of technical and non-technical requirements sought by their discipline's various stakeholders and that given accreditation issues with advisory board inputs would collectively suggest a need for a better understanding of their stakeholders needs as well. Finally, research into the "Web Portal" project (See page 133) has merit for further use of engineering tools in value-added processes (Porter, 1985).

References

The Green Report: Engineering Education for a Changing World. (1994). Downloaded, November 6, 2000 from the site: http://www.asee.org/publications/reports/greenworld.cfm. ASEE.

1997 Economic Census: Manufacturing Oklahoma. (2001). [On-Line @ http://www.census.gov/epcd/ec97/ok/OK000_31.HTM]. Washington, D.C.

1997 Economic Census: Summary Statistics for Oklahoma: 1997 NAICS Basis. (2001). [On-line @ http://www.census.gov/epcd/ec97/ok/OK000.HTM]. Washington, D.C.

Baldrige National Quality Program. (2001). [Education Criteria for Performance Excellence 2002]. On-line @ http://www.quality.nist.gov/: National Institute of Standards and Technology.

1997 Economic Census: Professional, Scientific, and Technical Services - Oklahoma. (2001). [On-Line @ http://www.census.gov/epcd/ec97/ok/OK000_54.htm#N541]. Washington, D.C.

1997 Economic Census: Summary Statistics for United States: 1997 NAICS Basis. (2001). [On-Line @ http://www.census.gov/epcd/ec97/us/US000.HTM]. Washington, D.C.

1997 Economic Census. (2001). [National Statistics by SIC]. On-line @ http://www.census.gov/econ/www/econ_cen.html: United States Census Bureau.

ABET. (2002). 2002-3 Engineering Criteria for Accrediting Engineering Programs. Baltimore, MD: ABET.

Altman, C., & Nair, I. (1996). Engineering in Context: An Empirical Study of Freshmen Students' Conceptual Frameworks. Journal of Engineering Education, 86(1), 317-132.

Armacost, R. L., Componation, P. J., Mullens, M. A., & Swart, W. W. (1994). An AHP Framework for Prioritizing Customer Requirements in QFD: An Industrialized Housing Application. IIE Transactions, 26(4), 72-79.

Badawy, M. K. (1995). Developing Managerial Skills in Engineers and Scientists, (2 ed.). New York, NY: Van Norstrand Reinhold.

Bard, J. (1992). A Comparison of the Analytical Hierarchy Process with Multiattribute Utility Theory: A Case Study. IIE Transactions, 24(5).

Benefield, L. D., Trentham, L. L., Khodadadi, K., & Walker, W. F. (1997). Quality Improvements in a College of Engineering Instructional Program. Journal of Engineering Education, 86(1), 57-64.

Bourne, J. R., Brodersen, A. J., Campbell, J. O., Dawant, M. M., & Shiavi, R. G. (1996). A Model for On-Line Learning Networks in Engineering Education. Journal of Engineering Education, 85(3), 253-262.

Boyer Commission Report. (1998) [1999, March].

Brassard, Michael & Ritter, Diane. (1994). The Memory Jogger II. Salem, NH: Goal/QPC.

Calantone, R. J., Di Benedetto, C. A., & Schmidt, J. B. (1999). Using the Analytic Hierarchy Process in New Product Screening. Journal of Product Innovation Management, 16(1), 65-76.

Carey, T. R. Total Quality Management in Higher Education: Why it Works; Why it Does Not. Unpublished doctoral dissertation, Rutgers, The State University of New Jersey.

Chan, F. T. S., Chan, M. H., & Tang, N. K. H. (2000). Journal of Materials Processing Technology, 107, 330-337.

Chan, L.-K., & Wu, M. (2002). Quality Function Deployment: A Literature Review. Vol. xxx, xxx-xxx.

Collins, T. R., Ph.D., P.E. Assistant Professor of Industrial Engineering, Department of Industrial Engineering, University of Arkansas. Interviews, July 10, 2002, October 17, 2002, and January 23, 2003.

Crutchfield, J. K. Senior Manager, Industrial Engineering, Integrated Defense Systems. Interviews and data collection, 3 April 2003, The Boeing Company, St. Louis site.

Dill, D. D., Massy, W. F., Williams, P. R., & Cook, C. M. (1996). Accreditation & Academic Quality Assurance: Can We Get There from Here? Vol. 28(5), 16-24. Washington, D.C.: Heldref Publications.

Diller, K., & Barnes, J. W. (1994). Adaptation of Total Quality Methods to the Administration of an Academic Engineering Department. Journal of Engineering Education, 83(5), 249-254.

Drake, P.R. (1998). Using the Analytic Hierarchy Process in Engineering Education. International Journal of Engineering Education 14(3), 191-196.

Duarte, J. E., & Coleman, E. More Effective Schools - A Quality Challenge. 42d Annual Quality Congress.

Easley, R. F., Valacich, J. S., & Venkataramanan, M. A. (2000). Capturing Group Preferences in a Multicriteria Decision. European Journal of Operations Research, 125(1), 73-83.

Evered, L. E. The Use of Analytic Decision Techniques for the Selection of Elective Mathematics Courses in Secondary Schools. Unpublished doctoral dissertation, Columbia University.

Expert Choice. (2002) Expert Choice, Inc. [Web Page]. [2002, May 4].

Fahnri, P., & Spatig, M. (1990). An Application-Oriented Guide to R & D Project Selection and Evaluation Methods. R & D Management, 20(2).

Feisel, L. D. The Changing Face of Engineering Education in the United States. Downloaded from http://www.ieee.org/organizations/eab/vp/a3.htm, 5/22/2002

Forman, E., & Peniwati, K. (1998). Aggregating Individual Judgments and Priorities with the Analytic Hierarchy Process. European Journal of Operations Research, 108(1), 165-169.

Fowler, F. J. Jr. (2002). Survey Research Methods (3 ed.). (Applied Social Research Methods No. 1). Thousand Oaks, California: Sage Publications, Inc.

Galvin, R. W. Trends in Engineering and science: An Industry View. The Bridge, 26(3&4). Downloaded from http://www.nae.edu/nae/naehome.nsf/weblinks/NAEW-4NHMEU?opendocument, 6/30/2002.

Han, C. H., Kim, J. K., Choi, S. H., & Kim, S. H. (1998). Determination of Information System Development Priority Using Quality Function Deployment. Computers and Industrial Engineering, 35(1-2), 241-244.

Hartmann, D. H. (2001). A Survey of Factors Influencing Web Portal Effectiveness. IEM 5743, Information Systems and Technology, Spring semester, Oklahoma State University.

Hillenmeyer, S. (1996). Reengineering and Quality Improvement in Higher Education. Journal of Innovative Management, 38-53.

Ho, E. S. S. A., Lai, Y. -J., & Chang, S. I. (1999). An Integrated Group Decision-Making Approach to Quality Function Deployment. IIE Transactions, 31(6), 553-567.

Hoff, K. G. A Model of a Technology Adoption Continuum Incorporating Risk Factors. Unpublished doctoral dissertation, Oklahoma State University.

Houshmand, A. A., Papadakis, C., McDonough, J. F., Fowler, T. W., & Markle, G. (1996). Methodology for Improving Quality of Instruction. Journal of Engineering Education, 85(2), 117-122.

Jack, E. P., Stephens, P. R., & Evans, J. R. (2001). An Integrative Summary of Doctoral Dissertation Research in Quality Management. Productions and Operations Management, 10(4), 363-382.

Jackson, B., Gordon, J. R. M., & Chisholm, J. D. (1996). A Learning Experience: The Technology Innovation Program. Journal of Engineering Education, 86(1), 309-316.

Johnson, V. R. (1998). Ask, and Ye Can Assess. Vol. 8(2). Washington, D.C.: American Society for Engineering Education.

Joiner, B. L. (1994). Fourth Generation Management: The New Business Consciousness. New York, NY: McGraw-Hill, Inc.

Juran, J. M. (1981). Product Quality: A Prescription for the West. Management Review, 70(6), 8-14.

Karapetrovic, S. Quality Assurance in the University System. Unpublished doctoral dissertation, University of Manitoba.

Kleiner, B. M. & Shewchuk, John P. (2001). Participatory Function Allocation in Manufacturing. Human Factors in Manufacturing. 11(3), 195-212.

Koksal, G., & Egitman, A. (1998). Planning and Design of Industrial Education Quality. Computers and Industrial Engineering, 35(3-4), 639-642.

Lai, V. S., Wong, B. K., & Cheung, W. (2002). Group Decision Making in a Multiple Criteria Environment: A Case Using the AHP in Software Selection. European Journal of Operations Research, 137(1), 134-144.

Lang, J. D., Cruse, S., McVey, F. D., & McMasters, J. (1999). Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers. Journal of Engineering Education, 88(1), 43-52.

Laurine, R. H., Jr. The Effectiveness of the Analytical Hierarchy Process for Prioritizing Software Defects Across the Software Maintenance Phase. Unpublished doctoral dissertation, The George Washington University.

Leedy, P. D. (1993). Practical Research: Planning and Design. 5 ed.). New York, New York: Macmillan Publishing Company.

Leepatanapan, S. An Industrial Needs Driven Curriculum Design Methodology and Its Application to Manufacturing in Thailand. Unpublished doctoral dissertation, University of Missouri - Rolla.

Litwhiler, D., & Kiemele, M. (1994). TQM and DOE in an Undergraduate Curriculum: Success Stories. Journal of Engineering Education, 83(3), 147-151.

Marose, R. A. Multicriteria Strategic Planning for the Mutual Life Insurance Company. Unpublished doctoral dissertation, Polytechnic Institute of New York.

McMillan, J. M. Total Quality Management in Higher Education: A Study of Senior Administrators' Perceptions About Total Quality Management in Institutions of Higher Education in Ohio. Unpublished doctoral dissertation, Kent State University.

National Science Board. (1993). Science & Engineering Indicators - 1993. Washington, DC: Government Printing Office.

Patton, M. Q. (1980). Qualitative Evaluation Methods. Beverly Hills, California: Sage Publications, Inc.

Payne, H. E. (1998). A Review of the Literature: Interactive Video Teletraining in Distance Learning Courses. Needham, MA: United States Distance Learning Association.

Porter, M. E. (1985). Competitive Advantage: Creating and Sustaining Superior Performance. New York, NY: The Free Press.

Puerzer, R. J., & Rooney, D. M. (2002). The Alumni Survey as an Effective Assessment Tool for Small Engineering Programs. Journal of Engineering Education, 91(1), 109-116.

Raschke, C. (1996). Digital Culture: The Third Knowledge Revolution and the Coming of the Hyperuniversity. Vol. 11(7), 16-25. San Jose, CA: Syllabus Press.

Regan, M., & Sheppard, S. (1996). Interactive Multimedia Coursewares and the Hands-on Learning Experience. Journal of Engineering Education, 85(2), 123-132.

Richards, T. C., & Mehreban, R. G. A Criteria for Measuring TQM in Higher Education. 48th Quality Congress.

Robbins, S. P. and De Cenzo, D. A. Supervision Today, 3/e. Upper Saddle River NJ: Prentice-Hall, 2001.

Rue, Leslie W. and Byars, Lloyd L. Supervision: Key Link to Productivity, 7/e. Boston: Irwin McGraw-Hill, 2001.

Saaty, T. L. (1986). Decision Making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World. Belmont, CA: Lifetime Learning Publications.

Saaty, T. L. (1988). The Analytical Hierarchy Process: Planning, Priority Setting, Resource Allocation. Pittsburgh, Pennsylvania: University of Pittsburgh.

Saaty, T. L. (2000). Fundamentals of Decision Making and Priority Theory with the Analytical Hierarchy Process (The Analytical Hierarchy Process Series No. VI). Pittsburgh, PA: RWS Publications.

Saaty, T. L., & Alexander, J. M. (1981). Thinking With Models: Mathematical Models in the Physical, Biological and Social Sciences (Modern Applied Mathematics and Computer Science No. 2). Oxford, England: Pergamon Press, Limited.

Saaty, T. L., & Alexander, J. M. (1989). Conflict Resolution: The Analytical Hierarchy Approach. New York, NY: Praeger Publishers.

Saaty, T. L., & Kearns, K. P. (1985). Analytical Planning: The Organization of Systems (The Analytical Hierarchy Process Series No. IV). Pittsburgh, PA: RWS Publications.

Saaty, T. L., & Vargas, L. G. (1991). The Logic of Priorities: Applications of the Analytical Hierarchy Process in Business, Energy, Health & Transportation (The Analytical Hierarchy Process Series No. III). Pittsburgh, PA: RWS Publications.

Sarin, S. (2002 February). [Letter to David H. Hartmann] with attached paper in process.

1997 SEASTAT Integrated Database. (2002). [SESTAT Data Files]. Science and Engineer Statistics Data System. Arlington, VA: National Science Foundation, Division of Science Resource Statistics.

Shelnutt, J. W., & Buch, K. (1996). Using Total Quality Principles for Strategic Planning and Curriculum Revision. Journal of Engineering Education, 85(3), 201-208.

SME. (1995a). Manufacturing Education for the 21st Century. Vol. I, Curricula 2002. Michigan: SME.

Smerdon, E. T. (1996). Lifelong Learning for Engineers: Riding the Whirlwind. The Bridge, 26(1&2). Downloaded from http://www.nae.edu/nae/naehome.nsf/weblinks/NAEW-4NHMJL?opendocument, 5/22/2002.

Sounderajan, N. (2002). Preparing for Accreditation Under EC 2000: An Experience Report. Journal of Engineering Education, 91(1), 117-123.

Swim, L. K. Improving Decision Quality in the Analytic Hierarchy Process Implementation through Knowledge Management Strategies. Unpublished doctoral dissertation, University of Oklahoma.

Swim, L.K., Ph.D. Director Decision Support, Integris Health. Interviews conducted July 9, 2002, October 23, 2002, and January 20, 2003 at 5300 N. Independence, Suite 230, Oklahoma City, OK, and by telephone [last two interviews], respectively.

Tavana, M., Kennedy, D. T., & Joglekar, P. (1996). A Group Decision Support Framework for a Consensus Ranking of Technical Manager Candidates. Journal of Management Science, 24(5), 523-538.

Tedesco, M. P. Strategic Change Management in Ship Design and Construction. Unpublished doctoral dissertation, Massachusetts Institute of Technology.

The Joint Task Force on Engineering Education Assessment. (1996). Assessment White Paper: A Framework for the Assessment of Engineering Education. Downloaded, November 6, 2000 from the site: http://www.asee.org/publications/reports/assessment.cfm. ASEE.

Todd, R. H., Sorensen, C. D., & Magleby, S. P. (1993). Designing a Senior Capstone Course to Satisfy Industrial Customers. Journal of Engineering Education, 82(2), 92-100.

Veerakool, V. An Analytical Hierarchy Approach to Establish the System Analyst's Knowledge Base for Selecting an Information Requirements Determination Strategy. Unpublished doctoral dissertation, University of Missouri - Rolla.

Wang, H., Xie, M., & Goh, T. N. (1998). A Comparative Study of the Prioritization Matrix Method and the Analytic Hierarchy Process Technique in Quality Function Deployment. Total Quality Management, 9(6), 421-430.

Warde, W. D. Sampling Methods. Stillwater, OK: Oklahoma State University.

Welch, S. C. Quality Function Deployment in Education Process Design. 48th Annual Quality Congress.

Wheelen, T. L., & Hunger, J. D. (1998). Strategic Management and Business Policy. New York, NY: Addison-Wesley Longman, Inc.

Wulf, W. A. (1998). The Urgency of Engineering Education Reform. The Bridge, 28(1). Downloaded from http://www.nae.edu/nae/naehome.nsf/weblinks/NAEW-4NHMKV?opendocument, 5/22/2002.

Zakarian, A., & Kusiak, A. (1999). Forming Teams: An Analytical Approach. IIE Transactions, 31(1), 85-97.

Appendixes

Appendix 1 - Oklahoma State University Institutional Review Board Form for Research Involving Human Subjects

Oklahoma State University
Institutional Review Board

Date : Thursday, September 26, 2002 IRB Application No EG031

Proposal Title: A PROCESS TO MODEL CUSTOMER-FOCUSED ENGINEERING PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

Principal
Investigator(s) :

David Hartmann	Kenneth Case
2801 Sweetbriar	332 En
Edmond, OK 74078	Stillwater, OK 74078

Reviewed and
Processed as: Exempt

Approval Status Recommended by Reviewer(s) : Pending Revision

---

You will need to make the following revisions to your research project before approval is granted. Please Submit a revised IRB application incorporating these changes. If you have questions, or wish to discuss the reviewers' comments, please schedule a meeting or call Dr. Carol Olson, Director of University Research Compliance (405-744-1676), or Sharon Bacher, IRB Executive Secretary (405-744-5700) in 415 Whitehurst.

The reviewers' comments are listed on the following page. To receive approval, they must be addressed and/or incorporated into the research protocol.

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modifications to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

Oklahoma State University
Institutional Review Board

Protocol Expires: 10/10/2003

Date: Tuesday, October 15, 2002 IRB Application No EG031

Proposal Title: A PROCESS TO MODEL CUSTOMER-FOCUSED ENGINEERING PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

Principal
Investigator(s):

David Hartmann	Kenneth Case
2801 Sweetbriar	332 En
Edmond, OK 74078	Stillwater, OK 74078

Reviewed and
Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 415 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

Oklahoma State University
Institutional Review Board

Reviewer Comments

Date : Thursday, September 26, 2002 IRB Application No EG031

Proposal Title: A PROCESS TO MODEL CUSTOMER-FOCUSED ENGINEERING PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

---

1) Given that superiors will know who participated, a list of names and addresses will maintained for follow-up surveys. Please provide a consent form.

2) Please explain where the participation list will be kept.

Signature Carol Olson

Carol Olson, Director of University Research Compliance

Thursday, September 26, 2002
Date

Appendix 2 – Structured Interview Questions

July 9, 2002: This is an planned 60 minute interview with Dr. Leva Swim, Integris Baptist Medical Center, Oklahoma City, OK. The purpose of the interview is to gain insight into the NGT process from an experienced practitioner.

May I cite this conversation within my dissertation?

May I record our conversation for the purpose of accuracy in documentation?

[Introduce self] "Hello, I am David Hartmann, interviewing ________, [date]. Would you please introduce yourself?"

[Ask interviewee to introduce himself or herself]

Content Data

Nominal group technique may be one of any number of methods to evoke verbal responses from a sample set. Why did you select NGT as your method?

How were you trained?

Approximately what number of NGT sessions did you conduct? By "session" I mean, one or more meetings that had one topic question as its purpose.

Is there only one recognized NGT method? If not, how did you choose?

Does NGT work and how did you know that it did? If not, then what did you do?

Please define "group".

How did you gain cooperation? Was a group ever disbanded in "mid-stream"?

Is NGT relevant, in your opinion for today's workplace and organization? If not, then what method?

How would you say NGT could be adapted to a virtual community?

NGT Sessions' Data Quality

Was it important to maintain the group's integrity during the session? By this I mean, what if people "floated" in and out?

Did you have one best way to conducting the meeting and what was that?

Did you maintain records of the meeting(s)?

How did you validate the meeting? For example, a sign-in sheet may document attendance.

There may be unexpected interviewer bias, influence, underlying the meetings. How would you say you tried to deal with interviewer bias?

Is there or are there any other comments that you would care to make about the Nominal Group Technique?

Thank you and good day.

Interview Documentation

Date:	July 9, 2002
Interviewee:	Leva Swim, Ph.D. *[title]*
Interviewer:	David Hartmann
Subject:	Nominal Group Technique [NGT]
Purpose:	The purpose of this interview is to gain insight into the NGT process from an experienced practitioner.
Setting:	This is a planned 1-hour, tape-recorded interview within the interviewee's business office.

PERSONAL INTERVIEW QUESTIONS

Purpose. The question set was designed to evoke impressions concerning their *individual* motivational behavioral tendencies, their opinions about the *"job"*, and their views toward the *organizational environment.* I wanted to observe patterns within each respondent and between the respondents.

Question: To what extent did electronic connectivity and information access promote or inhibit their motivation to create innovative ideas?

Instrument. Notes were taken during the interview.

---

1. Tell me about your professional career ladder. Where are you now?

2. Are you on a team? (Responses would lead to discussions regarding TQM, re-engineering, and other systems and processes re-evaluative mechanisms). If not, why not? If not now, were you ever on a professional team? Will you be on a team? By choice?

3. What is a virtual enterprise, business? Is a system of outsourcers, contract laborers/engineers?

4. Are you on-line in an electronic web? To whom are you connected? How often have you changed on-line services, if at all? Affirmative responses would lead to a discussion of hardware/software configurations, system standards, either self-managed or imposed. Negative responses would lead to discussions concerning their previous experiences and/or future expectancies concerning being placed within or choosing to be placed within an on-line system.

5. Do you have more than one web to which you are connected? For business or pleasure? What are you reporting responsibilities to the company: timelines, content, expectancies, resource requirements?

6. Tell me about your "typical" workday, hours, and breaks. Do you have a job or a task set to which you ascribe your daily professional activities?

7. How do you "find" co-workers and colleagues? Are you a hiring authority? Do you want to be?

8. What do you need from the organization? How does it know? What do you expect? How are you compensated? How are other telecommuters, such as yourself, compensated? How does that make you feel? What do you do, as a result of your feelings concerning the rewards from the company?

9. What keeps you going? Are you happy? Where would you like to be in three years, in five to ten years? Will you get there?

Thank you for your time

Appendix 3 – Research Phase I Review

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OKLAHOMA CITY AIR LOGISTICS CENTER (AFMC)
TINKER AIR FORCE BASE, OKLAHOMA

19 Dec 02

Mr. David H. Hartmann
322 Engineering North
Oklahoma State University
Stillwater OK 74078

Dear Mr. Hartmann:

OC-ALC/ENF has reviewed the research project you briefed to our engineering staff on 18 Dec 02. We approve the study to be conducted with members of our engineering community.

This approval remains in effect until 30 May 2003.

Sincerely,

Wayne Jones, PhD
Chief, OC-ALC Engineering Division

David H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

December 9, 2002

Dr. Wayne Jones
Chief, Science & Engineering division
OC-ALC-TIE
Tinker AFB, OK 73145

Dear Dr. Jones:

Thank you for the opportunity to brief you on the research I am conducting for the Ph. D., Industrial Engineering and Management, Oklahoma State University. To that end, my research advisor and I respectfully request your division's support.

I am at a critical (and time sensitive - sooner is much better) juncture in the dissertation effort and I need about 10 engineering managers (or engineering supervisors or trusted and seasoned engineers) for a 2-hour effort on-site. They would be attempting to identify characteristics of ideal graduate level (i.e., MS) engineers in a manufacturing environment (the very fact that Tinker deals with outside suppliers is a plus in this regard). The participants would then be asked to respond to two letters in which they would do individual inputting for about one hour each. Bottom line - 10 of the right people who would have about four hours each invested.

What's in it for Tinker? Potentially, it would lead to the ability to articulate engineering needs for future hires. It would also likely help Tinker assess educational programs for new and current hires. I am assured that from OSU's point of view, it would greatly help them (through my research) to understand the characteristics of graduate engineers from the point of view of the consumer (e.g., Tinker and its supporting suppliers), to then be aligned with thoughts, practices, and biases from the academic side. Of course, Tinker would receive any articles that distill the research effort into useful conclusions.

Dr. Jones, I have attached several documents to support my request, which are also saved to the attached floppy diskette. I will refer to several of them this morning:

- Tab 1 - Research project summary,
- Tab 2 - Project briefing slides presentation,
- Tab 3 - Participants' informed consent forms,
- Tab 4 - *Curriculum Vitae*, David H. Hartmann,
- Tab 5 - Suggested letter of soliciting participation, and
- Tab 6 - Suggested letter of approval for conducting the research.
- "Diskette"

Home: 405.359.3995 Dhartm0669@aol.com
Office: 405.974.2839 dhartmann@ucok.edu

Date:	**December 9, 2002**
Research Project:	**A Process To Model Customer-Focused Engineering Program Alignment By Means Of Group Consensus And Analytical Hierarchical Process Analysis**
Principle Investigator(s):	**Kenneth E. Case, Ph.D., Regents Professor, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma** **David H. Hartmann, Instructor, University of Central Oklahoma and Ph.D. Student, Industrial Engineering and Management, Oklahoma State University**

EXECUTIVE SUMMARY

Engineering graduate program outcomes and employer requirements must be effectively and efficiently aligned to provide graduates who are academically prepared to support the challenges and opportunities of contemporary manufacturing enterprises. Current assessment methods do not provide a demand-based approach to drive the eventual adoption and emphasis of engineering program topics and courses to achieve this alignment. The research project will develop a process that will align both manufacturing companies and colleges and universities in their expectations and programming for engineering graduates.

The Research Objective

The objective of this research project is to determine a methodology or sequential approach to operationalize the collective expectations of manufacturing stakeholders so as to align a graduate engineering program for industrial and engineering management programs by measuring the judgments of a specific research frame of engineering consumers - manufacturing companies. In sum, we need to know "what it takes to achieve alignment." The specific research frame will be limited to those companies in the State of Oklahoma. The research project will deliver a methodological process for alignment of engineering program outcomes and company needs validated by reference to an expert panel of faculty and industry representatives. The study has been designed using the methods for conducting descriptive survey research, because it is important to develop an understanding about the current status of the phenomena of goals alignment and then, to ultimately generalize to a broader set of engineering graduate consumers. By a "broader set of engineering graduates", it is assumed that the research could be expanded at a later date to include other research frames [other NAICS consumers, regions, and non-NAICS end users, such as government and higher education] and terminal degree levels [such as the associates and baccalaureate degrees].

Sub-objectives

In order to meet this objective of this research project, the following questions and objectives need to be answered:

Sub-objective 1.

What are the priorities of NAICS coded 31-33 manufacturing companies for the outcomes of a graduate engineering program?

Sub-objective 2.

Develop a general classification of graduate manufacturing engineering program outcomes.

Sub-objective 3.

What are the characteristics of engineering program alignment with the expectations of the ultimate consumer?

Sub-objective 4.

Are there differences between the graduate manufacturing engineering program outcomes and the priorities of NAICS coded 31-33 manufacturing companies. If there are differences, are they significant?

Project Time-Line - Manufacturing

• Study kick-off & Nominal Group Meeting	TBD
• Structured Interview & survey – part 1	TBD
• Delphi survey – part 2	Late January, 2003

Project Time-Line – Academics

• Study kick-off	9/16/02
• Structured Interview & survey – part 1	Early November
• Delphi survey – part 2	January, 2003

Methods to Answer the Sub-Objectives of the Research

Sub-objective 1. What are the priorities of NAICS coded 31-33 manufacturing companies for the outcomes of a graduate engineering program?

The following methodological steps will use primary and secondary data.

(1) Identify and meet with manufacturing companies in order to,
(2) Conduct NGT and Affinity Diagram sessions with manufacturing companies for weighted judgments, and to
(3) Analyze the groups' comparative judgments using analytical hierarchical processes and Expert Choice software (Expert Choice, 2002).

Sub-objective 2. Develop a general classification of graduate manufacturing engineering program outcomes.

The following methodological steps will use primary and secondary data.

(1) Review extant literature on curricula designs.
(2) Conduct structured interview of expert panel - academics.
(3) Develop a general model of graduate engineering programs and distribute to experts in a three step "Delphi method".
   a. Distribute and collect returned surveys of engineering program outcomes.
   b. Develop a first collective list of outcomes.
   c. Re-distribute list and collect second review using the affinities of technical, managerial, social, and political groups.
   d. Distribute final list for weighted judgments.
(4) Analyze comparative judgments using analytical hierarchical processes and Expert Choice software (Expert Choice, 2002).

Sub-objective 3. What are the characteristics of engineering program alignment?

(1) Conduct structured interview of expert panel – academics.
(2) Conduct structured interview of expert panel - manufacturing.
(3) Review extant literature on BNQA Education sector winners.
(4) Develop a collective list of characteristics.
(5) Develop a general model of graduate engineering programs and distribute to experts in a three step "Delphi method".
   a. Distribute and collect returned surveys of engineering program outcomes.
   b. Develop a first collective list of outcomes.
   c. Re-distribute list and collect second review.
   d. Distribute final list for weighted judgments.
(5) Analyze comparative judgments using analytical hierarchical processes.

Sub-objective 4. Are there differences between the graduate manufacturing engineering program outcomes and the priorities of NAICS coded 31-33 manufacturing companies. If there are differences, are they significant?

(1) Use ANOVA for checking the differences between the consistencies of the weighted judgments.

FACT SHEET

Who? David H. Hartmann, Ph.D. student, Oklahoma State University, Instructor, University of Central Oklahoma

Phone: 405.974.2839 [Office]
405.359.3995 [Home]

E-mail: dhartmann@ucok.edu

What? This is a research study of manufacturing companies, which seeks to determine a process to align manufacturing company-engineering needs with higher education's programs in Oklahoma and neighboring states.

When? During the next two to three months, 2002

Where? Oklahoma City Air Logistics Center

Why? Three levels of importance,

Primary Purpose
To develop a consensus position for Oklahoma manufacturing companies regarding master's degree level engineering candidate education.

Secondary Purpose
To deliver the research study.

Tertiary Purpose
To obtain research data for Mr. Hartmann's Ph.D. dissertation,

How? By facilitating a two-hour meeting with participating companies using the widely proven group consensus process known as the "Nominal Group Technique".

Resources required?

Approximately seven to ten representatives are needed for the meeting. This individual should be assigned in a "management" activity; have five or more years of engineering experience; and provided some input to one or more budget cycles.

FREQUENTLY ASKED QUESTIONS

What is the purpose of the research?
The research has three purposes:

> **Primary Purpose**
> To develop a consensus position for Oklahoma manufacturing companies regarding master's degree level engineering candidate education.
>
> **Secondary Purpose**
> To deliver the research study.
>
> **Tertiary Purpose**
> To obtain research data for Mr. Hartmann's Ph.D. dissertation,

Who are the subjects in the study?
There are two research groups in the study. The first is a group of seven to ten manufacturing company representatives, who have operations, budget, and engineering experience. The second group is comprised of manufacturing engineering faculty representatives from Oklahoma, Missouri, and Arkansas.

How will the subjects be sampled?
The subjects will be sampled in two stages. The first stage uses the "nominal group technique", a group consensus exercise designed to result in a common position on a topic. In the second stage, about one to two months after the group meeting, each member will be asked to complete a very brief questionnaire concerning the study. The questionnaire may have verbal responses in an interview format and written responses in a mailed survey format.

Will the participants encounter the possibility of stress or physical, psychological, or legal risks?
No. There are absolutely no questions asked of a personal nature beyond one's name and business address. No responses will be coded back to any individual, since a third party clerk will receive and "bank" all responses. No intentionally sensitive questions will be asked.

Will the subjects be deceived or misled in any way?
There will not be any intentional deception. The name and contact information of the researcher will be available for contact at any time throughout the study.

Will the subjects be presented with materials that might be considered offensive, threatening, or degrading?
No such materials will be offered the subjects.

Will any inducements be offered the subjects for their participation?
No.

Will a written consent form be used?
Yes. The subjects will be volunteers; the study will be explained to the sponsoring agency, and in the letter of invitation; and the purpose, confidentiality of the study will be briefly explained to the subjects once again prior to the study initiation.

Following our discussion, I will request a letter approving my conducting the research with members of the Science and Engineering Division. This letter supports an administrative matter required by the Institutional Review Board of Oklahoma State University.

Dr. Jones, I look forward to articulating the parameters of the research with you. I appreciate your valuable time to considering the project.

Respectfully,

David H. Hartmann

Attachments (7)

Home: 405.359.3995
Office: 405.974.2839
Dhartm0669@aol.com
dhartmann@ucok.edu

Manufacturers, Engineering, and Higher Education: A Research Study

Dave Hartmann
Principal Investigator

1

Today's Events

- (time interval) Introduction
- (time interval) Research Intro.
- (time interval) Research Session
- (time interval) Wrap-up & next steps

2

Introduction

- Background
- Research Problem
- "Why in-person data?"
- Confidentiality, non-disclosure, non-proprietary
- Other members of the research team
- "The Research Question"...

3

"The Research Question"...

"What do you expect in your unit's engineering candidates possessing a graduate degree in an engineering discipline?"

4

Research Project

- What is it?
  - Manufacturing & Academic Engineering Alignment Process [MAEAP]
  - Dual-track analyses: two groups
- Who's participating?
  - OC-ALC
  - Commercial companies
  - OSU, OU, UT, UT-Arlington, UA, UM-Rolla
- What time frame?
  - "Present" – March 2003

5

Project Stages

- Three Stages & Two Tracks

	Manufacturing	Engineering Schools
– 1	NGT & Affinity	Delphi
– 2	AHP	AHP
– 3	—— *Alignment consensus process* ——	

6

1

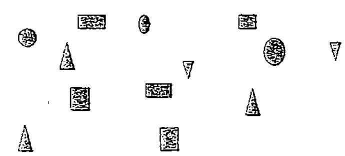
Nominal Group Technique

Research question

"What do you expect in your unit's engineering candidates possessing a graduate degree in an engineering discipline?"

7

Unclassified Ideas



8

Affinity Diagram

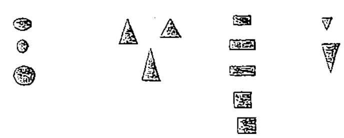
"A way to classify ideas into coherent relationships"

Technology	Management	Social	Political

9

Affinity Diagram

Technology	Management	Social	Political

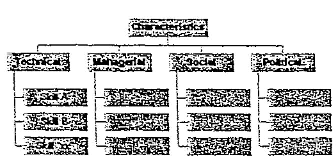


10

Analytical Hierarchy Process

--Paired Judgments--

Characteristics of a Graduate Engineer



11

Analytical Hierarchy Process

	Skill				
Skill	A	B	C	D	E
A	1				
B		1			
C			1		
D				1	
E					1

12

2

Our Next Steps

- Analytical Hierarchy Process
  - **A written response listing: 1 week turnaround; 1 hour completion**
- Alignment consensus process & written response to the question:

  "How would I define an aligned engineering program in my unit?"

  - **Approx. 1 week turnaround; 1 hour completion**

13

3

Oklahoma State University
322 EN
Stillwater, OK 74078

INFORMED CONSENT - Manufacturing

A. AUTHORIZATION

I,____________________, hereby authorize or direct Mr. David H. Hartmann or associates or assistants of his choosing, to perform the following treatment or procedure.

B. DESCRIPTION OF RESEARCH AND ASSOCIATED RISKS/BENEFITS

1. Research project is called: "A Process to Model Customer-Focused Engineering Program Alignment by Means of Group Consensus and Analytical Hierarchical Process Analysis".
2. This is exploratory research being conducted through Oklahoma State University by Mr. David Hartmann, Principal Investigator, doctoral student, School of Industrial Engineering and Management, OSU and Kenneth E. Case, Ph.D., doctoral advisor, School of Industrial Engineering and Management, OSU.
3. The purpose of the research is to obtain the written opinions of a group representing Oklahoma manufacturers regarding the qualifications of engineering graduates. The research project will begin 3 April 2003 and conclude 31 July 2003.
4. Research participants will be asked to meet [location to-be-determined] to provide verbal and written opinions in a commonly used research process known as the "Analytical Hierarchy Process technique." The participants will receive a mailed survey seeking their ranking the importance of data collected from a cohort of the research external to the group. Participants will not be asked to place their names on any documentation, except for one sign in roster, which will be kept for the purpose of the correct spelling of participants and for mailing of the future survey. No commercially proprietary information is required or solicited in this research. Mr. Hartmann will facilitate and lead the group discussion.
5. None of the procedures used in the project are experimental.
6. There are no intentional physical risks or discomfort to the participants.
7. The research participants should not expect any direct benefits from the research.
8. In this research, there are no known alternative data collection methods, which could replace the nominal group technique and written surveys.
9. Mr. Hartmann will keep the names of the participants obtained from the sign in roster and all data collected in the group meeting and from written surveys and confidential and secured in a locked file cabinet in its original form or as computer data diskettes.
10. This research does not foresee any risk beyond minimal risk expected in daily life answering a questionnaire and providing verbal responses to a question in a small group setting.
11. Whom to contact about the research: Mr. David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu, or postal address: D. H. Hartmann, 2801 Sweetbriar, Edmond, OK 73034.
12. Whom to contact about research subjects rights (the IRB office)
13. Additional contact: Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the principal investigator:

David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu,

Or postal address: D. H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

D. CONSENT DOCUMENTATION FOR WRITTEN INFORMED CONSENT

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________ Time: ____________________ (a.m./p.m.)

____

Name (typed) Signature

____

Signature of person authorized to sign for subject, if required

Witness(es) if required: ______________ Not / Required ______________

______________ Not / Required ______________

I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Signed: ____

Principal Investigator

12/8/2003

(Name)
(Address)

Dear (name):

The Oklahoma City Air Logistics Center. and the School of Industrial Engineering & Management at Oklahoma State University are conducting a study of Oklahoma manufacturers. The intent of the study is to determine what manufacturers need in their engineering employees that could be provided by college and university engineering programs in order to be more competitive. Your opinions, comments, and perceptions on the characteristics of the ideal engineer in your company will greatly contribute to the success of the study.

The first phase of the study is scheduled on (date), (time), (place). (Recommended response procedure)

The study has been designed in a way that you would not be asked any proprietary questions. An experienced researcher will conduct the study using a group interview process that will not ask for any information that could later be traced back to any particular individual. It is the "group's" opinion alone that will shape the outcome of the study.

Please consider the importance of this research and attend if at all possible. You may send a representative if you are unable to attend personally; please advise us of the attendee's name. The information you supply will be valuable to Oklahoma's colleges and universities in their efforts to provide the most appropriate engineering programs for your engineering employees. If you have any questions regarding the study, please contact David H. Hartmann, the principle investigator, at 405-974-2839, or via email at dhartmann@ucok.edu.

Thank you for your interest, assistance, and cooperation.

Sincerely

Nmae,
Title

(typist' initials)

☐ Yes, I am willing to participate in the study.

☐ No, I am not able to participate.

[Letterhead]

(Date)

Mr. David H. Hartmann
322 Engineering North
Oklahoma State University
Stillwater, Oklahoma 74078

Dear Mr. Hartmann:

(Agency name) has reviewed the research project you briefed to (person) on (date). We approve the study to be conducted with members of (business unit's name).

This approval remains in effect until 30 May 2003

Sincerely

(Name)
(Title)

David H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

12/17/2002

Research Participant:

Thank you for participating in today's research meeting.

The Oklahoma City Air Logistics Center and the School of Industrial Engineering & Management at Oklahoma State University are conducting a study of Oklahoma manufacturers. The intent of the study is to determine what manufacturers need in their engineering employees that could be provided by college and university engineering programs in order to be more competitive. Your opinions, comments, and perceptions on the characteristics of the ideal engineer in your company will greatly contribute to the success of the study.

The study has been designed in a way that you would not be asked any proprietary questions. An experienced researcher will conduct the study using a group interview process that will not ask for any information that could later be traced back to any particular individual. It is the "group's" opinion alone that will shape the outcome of the study.

The information you supply will be valuable to Oklahoma's colleges and universities in their efforts to provide the most appropriate engineering programs for your engineering employees. If you have any questions regarding the study, please contact David H. Hartmann, the principle investigator, at 405-974-2839, or via email at dhartmann@ucok.edu.

Thank you for your interest, assistance, and cooperation.

Sincerely

David H. Hartmann
Principal Investigator

Home: 405.359.3995 Email: Dhartm0669@aol.com
Office: 405.974.2839 Email: dhartmann@ucok.edu

Appendix 4 – Research Phase II Review

David H. Hartmann
2801 Sweetbriar
Edmond, Oklahoma 73034-6554
Dhartm0669@aol.com

January 15, 2004

["Participant"]
OC-ALC/XXXXX
3001 Staff Drive
Tinker Air Force Base, Oklahoma 73145-3001

Dear ["Participant"]:

Thank you very much for your participation in the Oklahoma City Air Logistics Center and the School of Industrial Engineering & Management, Oklahoma State University study of Oklahoma manufacturers. As you may recall, the intent of the study is to determine what manufacturers need in their graduate engineering employees that could be provided by college and university engineering programs to help the manufacturers be more competitive. This letter is a status report and the introduction of Phase 2 of the research project – the phase where I need your help very much.

Phase 1. This phase was completed late December 2002. To recap -- four ideas motivated the team's brainstorming a set of graduate engineering criteria: *technical, managerial, social,* and *political* criteria [Tab 1]. Our research team then developed a "consensus of research findings", which the team grouped under one of those four criteria [Tab 2].

Phase 2. As briefed in December, the research project proposed to use a decision-analysis tool known in statistical research as "analytical hierarchy processes" [AHP]. AHP takes a problem and breaks-down the decisions resolving the problem into subordinate parts. In a way, this model resembles a multi-level building, where the top floor is the desired outcome of the decisions and is called Level "0"; the next level down is "Level 1"; and so forth. In this research project, Level 0 is the "ideal graduate engineering candidate."

["Participant"], since the December team meeting, I arbitrarily labeled the *technical, managerial, social,* and *political* criteria as **Level 1**. I also labeled our "consensus of research findings" -- **Level 2**.

In phase 2, we request you review the **Level 1** and **Level 2** data and to provide feedback. Your feedback is very important, because it will be used to build a questionnaire to assess the importance of the criteria manufacturers need in their engineering employees.

 (Next page please)

The enclosed package contains the background and findings from the December meeting (Tabs 1 and 2). It also provides additional information for your review (Tabs 3 & 4).

Team -- Here's what we need to do in Phase 2:

- Tab 1: Provided for your information are the original findings transcribed from the charts completed during the December meeting. **No comment is requested here**.
- Tab 2: Provided FYI are the original definitions for the *technical, managerial, political,* and *social* criteria.

  NOTE: **If you wish to comment on the original definitions, an area is blocked out for you to propose changes. Please leave blank, if you are satisfied with the given definitions.**

- Tab 3: Provided are December's *technical, managerial, social,* and *political* criteria (shown under the column label **"Level 1"**); the team's consensus, grouped findings (shown as **"Level 2"**). Also shown are proposed definitions for the Level 2 criteria. This proposal is based upon the oral comments made by the participants as understood by the researcher and his assistant.

  NOTE: **Using the original Level 1 definitions (Tab 2), please review these proposed definitions and make any needed changes directly upon the page – continue onto the back of the page(s) as necessary. If satisfied a definition is appropriate, continue with your review.**

- Tab 4: Note the columns labeled Level 3, Level 4, Delete, and Reason(s) for Change. Then using the given **"Level 1"** and **"Level 2"** criteria, please make the following three assessments:

  ⇨ In a given level 1 area [technical, managerial, social, political], if a level 2 criterion appears to be subordinate to another criterion, and should be changed to level 3 or level 4, **then signify your selection by placing check mark or "X" besides it, and indicate "reasons for change"**;

  Or

  ⇨ In a given level 1 area, if level 2 criterion should be eliminated, because it is already included, unneeded, etc., **please place a check mark or "X" besides it, and indicate "reasons for change"**;

  Or

  ⇨ If a level 2 criterion should be moved under another Level 1 area, then **indicate this change under "Reason(s) for Change"**.

Your continued voluntary participation is essential to the success of the research.

(Next page please)

["Participant"], I request you complete the review and return your package by 3 March 2003. A self-addressed stamped envelope is included for your convenience.

Should you have any questions regarding Phase 2 or any other questions concerning the Project please contact me, the principle investigator, at 405-974-2839 or via email at dhartmann@ucok.edu as soon as possible.

I am very grateful for your interest, assistance, and cooperation.

Respectfully,

David H. Hartmann
Principal Investigator

Encl.: (1)

CC: Wayne Jones, Ph.D.,
Each team member,
Kenneth Case, Ph.D.

Technical

Science & math background
Application of the basics
Technical expert in particular field [skill]
Able to define the problem – problem solving overall
Able to analyze using specific tools – economic engineering, risk analysis
Computer literate
Knowledge of industry standards
Able to sell ideas to others
ISO 9002
Failure analysis techniques
Be trainable
Hands on experience -- internships/co-ops
Hands on experience -- machining, lathe, milling @ vo-tech
Did you have "real world" experience b/w degrees?

Managerial

Problem solving skills: breaking down into smaller elements
Able to analyze (i.e. engineering economics)
Plan a project, manage projects and budget estimates
Understand lean management in an overall environment
Understand the difference between repair and new manufacturing
Self-motivated
Seeks challenges/new ideas
Be able to chair meetings [plan & direct]
Multi-tasking [good time management]
Smoothly transition roles as a leader and a team player
Be trainable
Skill as a mentor: help others/foster development beyond training

Political

ID people & relationships in a variety of organizations as resources
Ability to convert organizational goals into source of influence: individual & teams
Lack of political inclination (influence/respect vs. power)
Be adaptable
Able to maintain valuable alliances
Knowledge of which "fight to fight" and which one "not to fight": pick your battles
Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")

Social

Good communication skills: able to switch gears and direct communication appropriately – change in audience
Common sense
Good attitude
Create a "win-win" atmosphere
Confidence and enthusiasm
Relevant communication skills via computers [email]
Form working relationships with a variety of people
Aware and willing to "earn" respect in a manufacturing environment
Communicate well both orally [info, persuasive] and written [info, persuasive]
Sell ideas to others
Be a team player
Get along in professional dynamics: how to get along in a group and with individual
Skill as a mentor: help others, foster development beyond training
Listen and accept instructions
Able to give and take constructive criticism: professionalism, do not take things personally

Working Definitions

Social Competence: <u>The ability to work with, understand, communicate with and motivate other people, both individually and in groups</u>. Comments or changes recommended:

Political: <u>Ability to enhance his or her power, build a power base, and establish "right" connections in the organization</u>. Comments or changes recommended:

Managerial: Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Comments or changes recommended:

Technical skills: Specialized knowledge and expertise used to carry out particular techniques or procedures.

Comments or changes recommended:

Level 1	Level 2	Definition of Level 2 Engineering Factor
Technical	Science & math background	Received college-level academic credit for science and mathematics
	Application of the basics	Has practical evidence of using science, math, and engineering in practice
	Technical expert in particular field [skill]	Academic credit received for more than one course in subject area
	Able to define the problem – problem solving overall	Able to show evidence of using a scientific method
	Able to analyze using specific tools – economic engineering, risk analysis	Able to use engineering formulae and processes basic to project management
	Computer literate	Demonstrated practice in use of basic computer tools such as word processing, spreadsheet, and computer-assisted engineering tools
	Knowledge of industry standards	Is familiar with standards used in the industry, not including international standards such as ISO.
	Able to sell ideas to others	Demonstrated experience as product or process champion
	ISO 9002	Demonstrated familiarity with ISO 9002
	Failure analysis techniques	Familiar with FMEA
	Be trainable	Demonstrated completion of processes designed to improve technical competence in non-academic credit awarding courses.
	Hands on experience -- internships/co-ops	Completed an internship or co-op experience
	Hands on experience -- machining, lathe, milling @ vo-tech	Demonstrated experience in basic machining skills
	Did you have "real world" experience b/w degrees?	Following undergraduate degree, does the candidate have practical work experience?

Level 1	Level 2	Definition of Level 2 Engineering Factor
Managerial	Problem solving skills: breaking down into smaller elements	Evidence of using scientific method
	Able to analyze (i.e. engineering economics)	Able to use methodological basic engineering formulae
	Plan a project, manage projects and budget estimates	Knowledgeable and demonstrate practical experience in project management skills
	Understand lean management in an overall environment	Knowledgeable of "lean manufacturing"
	Understand the difference between repair and new manufacturing	[Self-explanatory]
	Self-motivated	Works without supervisory oversight in most endeavors
	Seeks challenges/new ideas	Demonstrates interest in jobs requiring data or opinion beyond the candidate's close work unit.
	Be able to chair meetings [plan & direct]	Able to develop meeting agenda, run meetings, and oversee follow-up
	Multi-tasking [good time management]	Can manage more than one project at a time
	Smoothly transition roles as a leader and a team player	Shows ability to serve in multiple capacities
	Be trainable	Demonstrated completion of processes designed to improve managerial competence in non-academic credit awarding courses.
	Skill as a mentor: help others/foster development beyond training	Served as a training leader for one or more peers and/or subordinates

Level 1	Level 2	Definition of Level 2 Engineering Factor
Political	ID people & relationships in a variety of organizations as resources	Able to show the relationship of people in various roles both inside and outside of the work unit
	Ability to convert organizational goals into source of influence: individual & teams	Can relate the overall mission into the operational procedures of the work unit
	Lack of political inclination (influence/respect vs. power)	Able to show that work is related to the outcome of the unit and not to the improvement of one's resume'
	Be adaptable	Demonstrates ability to serve in a variety of work roles and environments
	Able to maintain valuable alliances	Able to show resource cooperation over a six-month period of time
	Knowledge of which "fight to fight" and which one "not to fight": pick your battles	Can show ability to manage projects in budget reduction periods
	Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")	Served in a verity of projects internal and external to the work unit.

Level 1	Level 2	Definition of Level 2 Engineering Factor
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience	Able to speak to a variety of audiences
	Common sense	Primarily uses data as basis of decisions, but allows for group consensus.
	Good attitude	Positively contributes to promotion of the unit's culture
	Create a "win-win" atmosphere	Able to support multiple outcomes in a project
	Confidence and enthusiasm	Able to show proactive support for a group
	Relevant communication skills via computers [email]	Completed training or academic credit courses in business communications
	Form working relationships with a variety of people	Demonstrated membership in one or more groups within and without the work unit
	Aware and willing to "earn" respect in a manufacturing environment	Demonstrated peer experience in subordinate & superior relationships
	Communicate well both orally [info, persuasive] and written [info, persuasive]	Able to show group consensus achieved through oral, written and electronic communications media
	Sell ideas to others	Demonstrated competence in persuasive communications media
	Be a team player	Sable to serve in a variety of roles in a work unit
	Get along in professional dynamics: how to get along in a group and with individual	Practical experience in team projects
	Skill as a mentor: help others, foster development beyond training	Demonstrated experience as a trainer of others
	Listen and accept instructions	Demonstrated experience in understanding procedures and project requirements
	Able to give and take constructive criticism: professionalism, do not take things personally	Uses a variety of techniques to clarify and to reach consensus on requirements of tasks.

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Technical	Science & math background				
	Application of the basics				
	Technical expert in particular field [skill]				
	Able to define the problem – problem solving overall				
	Able to analyze using specific tools -- economic engineering, risk analysis				
	Computer literate				
	Knowledge of industry standards				
	Able to sell ideas to others				
	ISO 9002				
	Failure analysis techniques				
	Be trainable				
	Hands on experience -- internships/co-ops				
	Hands on experience -- machining, lathe, milling @ vo-tech				
	Did you have "real world" experience b/w degrees?				

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Managerial	Problem solving skills: breaking down into smaller elements				
	Able to analyze (i.e. engineering economics)				
	Plan a project, manage projects and budget estimates				
	Understand lean management in an overall environment				
	Understand the difference between repair and new manufacturing				
	Self-motivated				
	Seeks challenges/new ideas				
	Be able to chair meetings [plan & direct]				
	Multi-tasking [good time management]				
	Smoothly transition roles as a leader and a team player				
	Be trainable				
	Skill as a mentor: help others/foster development beyond training				

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Political	ID people & relationships in a variety of organizations as resources				
	Ability to convert organizational goals into source of influence: individual & teams				
	Lack of political inclination (influence/respect vs. power)				
	Be adaptable				
	Able to maintain valuable alliances				
	Knowledge of which "fight to fight" and which one "not to fight": pick your battles				
	Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")				

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience				
	Common sense				
	Good attitude				
	Create a "win-win" atmosphere				
	Confidence and enthusiasm				
	Relevant communication skills via computers [email]				
	Form working relationships with a variety of people				
	Aware and willing to "earn" respect in a manufacturing environment				
	Communicate well both orally [info, persuasive] and written [info, persuasive]				
	Sell ideas to others				
	Be a team player				
	Get along in professional dynamics: how to get along in a group and with individual				
	Skill as a mentor: help others, foster development beyond training				
	Listen and accept instructions				
	Able to give and take constructive criticism: professionalism, do not take things personally				

Appendix 5 - Survey Pretest in Research Phase II Review

Academic Outcomes Questionnaire

Hello. This brief questionnaire asks you for your opinion about the desirable outcomes in the graduate engineering student you educate for employment in a manufacturing setting.

In the first part, you will be asked about a general classification of graduate manufacturing engineering program outcomes.

In the second part, you will be asked about alignment of manufacturing needs and program outcomes.

In a future mailing, you will be asked to consider the opinions of other engineering educators so that the respondent group will approach a consensus on the desirable outcomes for a graduate manufacturing engineer.

We thank you very much for your valuable time and promise to make this survey very brief. Remember, this survey is entirely confidential. Your name will not appear on the data collected and you will not be identified to other participants in this study.

If you have any questions about this survey, please call the Principal Investigator, Dave Hartmann, at (405) 359-3995, or use the e-mails at Dhartm0669@aol.com.

I would be very happy to assist you in any way to better understand this survey.

Part 1. Graduate Manufacturing Engineering Outcomes

In the space below, please write down as many outcomes as possible, which should result in every engineering graduate student. Please attach additional sheets, if required.

Please attempt to classify the outcomes you identified under general headings, such as theory, practice, ethics, communicative skills, etc. Please attach additional sheets, if required.

Part 2. Understanding the Alignment of Manufacturing Needs and Engineering Graduate Students

In the space below, please write down the first five things that come to mind when you think about how close your engineering candidates currently match contemporary manufacturing company's engineering needs.

1. TECHNICAL COMPETENCIES (ENGINEERING ~~PREPARADNESS~~) PREPARADNESS
2. PROBLEM SOLVING
3. RESEARCH CAPABILITES
4. MANAGING PROJECTS
5. COST ESTIMATION

In the space below, please write down what you want in your engineering graduates in the role of candidates for manufacturing engineering employment.

1. PREPARED FOR ENGINEERING CHALLENGES
2. MANAGEMENT SKILLS
3. COMMUNICATION SKILLS
4. TEAM WORK ENVIRONMENT
5. EASILY ADAPTABLE TO CHANGING WORK ENVIRONMENT

Considering the word "Alignment", please write down the first five things this word means to you when you read the following statement:

"Engineering schools and manufacturing must work together to have graduate students aligned to my manufacturing business requirements."

1. MEET CURRENT NEEDS OF EMPLOYER
2. UNDER STAND NEW TECHNOLOGIES
3. INDUSTRY SHOULD PROVIDE FEEDBACK TO UNIVERSITIES THROUGH ADVISORY BOARDS ON WHAT THEY NEED IN NEW GRADS.
4. ABILITY TO QUICKLY ADAPT TO THE FAST-PACED GLOBALLY COMPETITIVE ENVIRONMENT OF THE MFG INDUSTRY.
5. WORK ON INTERDISPLINARY CROSS-FUNCTIONAL TEAMS FOR PROCESS/PRODUCT DEVELOPMENT.

Oklahoma State University
School of Industrial Engineering & Management

(Date)

Dear Engineering Educator,

I am David Hartmann, a doctoral candidate at Oklahoma State University. I am conducting a study of engineering outcomes from manufacturing engineering programs. The intent of the study is to determine the characteristics of the engineering student holding the graduate degree, which manufacturers desire in their engineering employees to be competitive in their respective markets. In addition the research investigates the student's characteristics alignment between academic outcome and manufacturing requirements.

To pursue this research two paths of inquiry are ongoing -- academic and manufacturing. The manufacturing perceptions are complete. We now seek a consensus opinion of a select group of engineering academicians.

Your opinions, comments, and perceptions on the characteristics of the ideal engineering graduate student completing a curriculum towards an advanced degree will greatly contribute to the success of the study.

Request you identify an engineering educator generally conforming to the following specifications:

- The individual has earned the terminal Ph.D. in an engineering discipline;
- The panel member is a professional engineer as defined by the particular state's board of engineering registration in the state of their faculty assignment; and
- The panel member has been directly involved with the engineering department's business advisory committee or similar such committee.

The research project should not take any more than one hour to complete in three brief questionnaires during February 2003 – three hours total.

We have enclosed a stamped self-addressed post card on which you can indicate your preference to participate in the study.

The study has been designed in a way that you would not be asked any sensitive questions. The study will be conducted by an experienced researcher using a three step Delphi group process that will not ask for any information, which later could be traced to any particular individual in the study. It is the "group's" opinion alone that will shape the outcome of the study. A survey will be sent to the member you nominate.

Respectfully, we request your reply by 1 February 2003.

If you have any questions regarding the study, please contact David H. Hartmann at (405) 974-2839 or e-mail at dhartmann@ucok.edu.

Thank you for your interest, assistance, and cooperation.

Sincerely,

David H. Hartmann
Researcher

Encl.: (1) Reply postcard

Industrial Requirements Survey

This survey follows up on the research conducted in mid-December 2002. It asks you to comparatively judge between an engineering candidate's knowledge, skills or competencies [factors]. Assume that these factors are gained through a graduate engineering education program. Further, assume the candidate is competing for a job in your unit.

In this survey, you will make comparative judgments between engineering factors on a scale ranging from "extremely more important" to "extremely less important". For simplicity, we will represent these judgments using the numerals "plus 9" to a "minus 9" in single digit increments, for example, 9, 8, 7...-7, -8, & -9. The numeral 1 is the midpoint and represents factors of about the same level of importance. For example, comparing a factor to itself would result in a judgment of "1".

Let's look at a commonplace example facing ordinary consumers – "purchasing a new car."

Several "factors" you could use to choose one vehicle over another might be **price, available options, standard equipment**, and so on. While each factor is important for making a final "best" decision, however, in comparing them side-by-side one factor might be more or less important than another factor. So, let's compare just **price** and **standard equipment**.

Example question #1.
"When buying a new car or truck, ***price*** is <u>(how important)</u> compared to ***standard features***?"

1	+2	+3	+4	+5	+6	+7	+8	+9
About the same		Slightly more important		Strongly more important		Very strongly more important		Extremely more important

1	-2	-3	-4	-5	-6	-7	-8	-9
About the same		Slightly less important		Strongly less important		Very strongly less important		Extremely less important

Please circle the number above which states your judgment about how important ***price*** is to ***standard features.***

Now, using the same rankings as, ***Example question #1,*** but removing the text:

Example question #2.
"When buying a new car or truck, ***price*** is <u>(how important)</u> compared to ***available options***?" Circle your judgment.

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Part 1, "**Industrial Requirements Survey"** will resemble example question #2. Please use pencil to mark your answers. There are no "right answers". However, if you want to change your answer, completely erase your first response and mark your revised judgment.

Thank you for your valuable time completing this survey.

Part 1. Managerial, Technical, Social, and Political Factors

Consider the relative importance of ***management, technical, social,*** and ***political*** factors. Then using the **+9 [Plus Nine]** to **–9 [Minus Nine]** judgment scales previously described, please compare the following factors and circle one number corresponding to your judgment. The factors your research team agreed upon as part of the candidate engineer's background are shown in **bold print**.

"Given you want to employ the most qualified engineering graduate degree candidate."

1.1 How important is **Managerial** compared to **Technical**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2 How important is **Managerial** compared to **Social**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3 How important is **Managerial** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4 How important is **Technical** compared to **Social**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.5 How important is **Technical** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.6 How important is **Social** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Managerial

Consider the engineering factor -- **Managerial**. Please compare the following factors and circle one number corresponding to your choice:

1.1.1 How important is **Problem solving skills: breaking down into smaller elements** compared to **Able to analyze (i.e. engineering economics)**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.2 How important is **Problem solving skills: breaking down into smaller elements** compared to **Plan a project, manage projects and budget estimates?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.3 How important is **Problem solving skills: breaking down into smaller elements** compared to **Understand lean management in an overall environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.4 How important is **Problem solving skills: breaking down into smaller elements** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.5 How important is **Problem solving skills: breaking down into smaller elements** compared to **Self-motivate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.6 How important is **Problem solving skills: breaking down into smaller elements** compared to **Seek challenges/new ideas**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.7 How important is **Problem solving skills: breaking down into smaller elements** compared to be **Able to chair meetings [plan & direct]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.8 How important is **Problem solving skills: breaking down into smaller elements** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.9 How important is **Problem solving skills: breaking down into smaller elements** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.10 How important is **Problem solving skills: breaking down into smaller elements** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.11 How important is **Problem solving skills: breaking down into smaller elements** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.12 How important is **Able to analyze (i.e. engineering economics)** compared to **Plan a project, manage projects and budget estimates**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.13 How important is **Able to analyze (i.e. engineering economics)** compared to **Understand lean management in an overall environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.14 How important is **Able to analyze (i.e. engineering economics)** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.15 How important is **Able to analyze (i.e. engineering economics)** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.16 How important is **Able to analyze (i.e. engineering economics)** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.17 How important is **Able to analyze (i.e. engineering economics)** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.18 How important is **Able to analyze (i.e. engineering economics)** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.19 How important is **Able to analyze (i.e. engineering economics)** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.20 How important is **Able to analyze (i.e. engineering economics)** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.21 How important is **Able to analyze (i.e. engineering economics)** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.22 How important is **Plan a project, manage projects and budget estimates** compared to **Understand lean management in an overall environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.23 How important is **Plan a project, manage projects and budget estimates** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.24 How important is **Plan a project, manage projects and budget estimates** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.25 How important is **Plan a project, manage projects and budget estimates** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.26 How important is **Plan a project, manage projects and budget estimates** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.27 How important is **Plan a project, manage projects and budget estimates** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.28 How important is **Plan a project, manage projects and budget estimates** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.29 How important is **Plan a project, manage projects and budget estimates** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.30 How important is **Plan a project, manage projects and budget estimates** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.31 How important is **Understand lean management in an overall environment** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.32 How important is **Understand lean management in an overall environment** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.33 How important is **Understand lean management in an overall environment** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.34 How important is **Understand lean management in an overall environment** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.35 How important is **Understand lean management in an overall environment** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.36 How important is **Understand lean management in an overall environment** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.37 How important is **Understand lean management in an overall environment** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.38 How important is **Understand lean management in an overall environment** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.39 How important is **Understand the difference between repair and new manufacturing** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.40 How important is **Understand the difference between repair and new manufacturing** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.41 How important is **Understand the difference between repair and new manufacturing** compared to **Able to chair meetings [plan & direct]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.42 How important is **Understand the difference between repair and new manufacturing** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.43 How important is **Understand the difference between repair and new manufacturing** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.44 How important is **Understand the difference between repair and new manufacturing** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.45 How important is **Understand the difference between repair and new manufacturing** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.46 How important is **Self-motivate** compared to **Seek challenges/new ideas**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.47 How important is **Self-motivate** compared to **Able to chair meetings [plan & direct]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.48 How important is **Self-motivate** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.49 How important is **Self-motivate** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.50 How important is **Self-motivate** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.51 How important is **Self-motivate** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.52 How important is **Seek challenges/new ideas** compared to **Able to chair meetings [plan & direct]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.53 How important is **Seek challenges/new ideas** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.54 How important is **Seek challenges/new ideas** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.55 How important is **Seek challenges/new ideas** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.56 How important is **Seek challenges/new ideas** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.57 How important is **Able to chair meetings [plan & direct]** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.58 How important is **Able to chair meetings [plan & direct]** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.59 How important is **Able to chair meetings [plan & direct]** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.60 How important is **Able to chair meetings [plan & direct]** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.61 How important is **Multi-tasking [good time management]** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.62 How important is **Multi-tasking [good time management]** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.63 How important is **Multi-tasking [good time management]** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.64 How important is **Smoothly transition roles as a leader and a team player** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.65 How important is **Smoothly transition roles as a leader and a team player** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.66 How important is **Be trainable** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Technical

Consider the engineering factor -- **Technical**, please compare the following factors and circle the number corresponding to your choice:

1.2.1 How important is **Science & math background** compared to **Application of the basics**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.2 How important is **Science & math background** compared to **Technical expert in particular field [skill]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.3 How important is **Science & math background** compared to **Able to define the problem – problem solving overall**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.4 How important is **Science & math background** compared to **Able to analyze using specific tools – economic engineering, risk analysis**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.5 How important is **Science & math background** compared to **Computer literate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.6 How important is **Science & math background** compared to **Knowledge of industry standards**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.7 How important is **Science & math background** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.8 How important is **Science & math background** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.9 How important is **Science & math background** compared **to Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.10 How important is **Science & math background** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.11 How important is **Science & math background** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.12 How important is **Science & math background** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.13 How important is **Science & math background** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.14 How important is **Application of the basics** compared to **Technical expert in particular field [skill]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.15 How important is **Application of the basics** compared to **Able to define the problem – problem solving overall**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.16 How important is **Application of the basics** compared to **Able to analyze using specific tools – economic engineering, risk analysis**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.17 How important is **Application of the basics** compared to **Computer literate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.18 How important is **Application of the basics** compared to **Knowledge of industry standards**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.19 How important is **Application of the basics** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.20 How important is **Application of the basics** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.21 How important is **Application of the basics** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.22 How important is **Application of the basics** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.23 How important is **Application of the basics** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.24 How important is **Application of the basics** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.25 How important is **Application of the basics** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.26 How important is **Technical expert in particular field [skill** compared to **Able to define the problem – problem solving overall**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.27 How important is **Technical expert in particular field [skill** compared to **Able to analyze using specific tools – economic engineering, risk analysis**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.28 How important is **Technical expert in particular field [skill** compared to **Computer literate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.29 How important is **Technical expert in particular field [skill** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.30 How important is **Technical expert in particular field [skill** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.31 How important is **Technical expert in particular field [skill** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.32 How important is **Technical expert in particular field [skill** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.33 How important is **Technical expert in particular field [skill** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.34 How important is **Technical expert in particular field [skill** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.35 How important is **Technical expert in particular field [skill** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.36 How important is **Technical expert in particular field [skill** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.37 How important is **Able to define the problem – problem solving overall** compared to **Able to analyze using specific tools – economic engineering, risk analysis?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.38 How important is **Able to define the problem – problem solving overall** compared to **Computer literate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.39 How important is **Able to define the problem – problem solving overall** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.40 How important is **Able to define the problem – problem solving overall** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.41 How important is **Able to define the problem – problem solving overall** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.42 How important is **Able to define the problem – problem solving overall** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.43 How important is **Able to define the problem – problem solving overall** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.44 How important is **Able to define the problem – problem solving overall** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.45 How important is **Able to define the problem – problem solving overall** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.46 How important is **Able to define the problem – problem solving overall** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.47 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Computer literate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.48 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.49 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.50 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.51 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.52 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.53 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.54 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.55 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.56 How important is **Computer literate** compared to **Knowledge of industry standards**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.57 How important is **Computer literate** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.58 How important is **Computer literate** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.59 How important is **Computer literate** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.60 How important is **Computer literate** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.61 How important is **Computer literate** compared to **Hands on experience -- internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.62 How important is **Computer literate** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.63 How important is **Computer literate** compared to **Did you have "real world" experience b/w degrees**??

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.64 How important is **Knowledge of industry standards** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.65 How important is **Knowledge of industry standards** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.66 How important is **Knowledge of industry standards** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.67 How important is **Knowledge of industry standards** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.68 How important is **Knowledge of industry standards** compared to **Hands on experience -- internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.69 How important is **Knowledge of industry standards** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.70 How important is **Knowledge of industry standards** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.71 How important is **Able to sell ideas to others** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.72 How important is **Able to sell ideas to others** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.73 How important is **Able to sell ideas to others** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.74 How important is **Able to sell ideas to others** compared to **Hands on experience -- internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.75 How important is **Able to sell ideas to others** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.76 How important is **Able to sell ideas to others** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.77 How important is **ISO 9002** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.78 How important is **ISO 9002** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.79 How important is **ISO 9002** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.80 How important is **ISO 9002** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.81 How important is **ISO 9002** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.82 How important is **Failure analysis techniques** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.83 How important is **Failure analysis techniques** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.84 How important is **Failure analysis techniques** compared to **Hands on experience -- machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.85 How important is **Failure analysis techniques** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.86 How important is **Be trainable** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.87 How important is **Be trainable** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.88 How important is **Be trainable** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.89 How important is **Hands on experience – internships/co-ops** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.90 How important is **Hands on experience – internships/co-ops** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.91 How important is **Hands on experience – machining, lathe, milling @ vo-tech** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Social

Considering the engineering factor: **Social**, please compare the following factors and circle the number corresponding to your choice:

1.3.1 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Common sense?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.2 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Good attitude?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.3 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Create a "win-win" atmosphere?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.4 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.5 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Relevant communication skills via computers [email]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.6 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Form working relationships with a variety of people**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.7 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.8 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.9 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.10 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Be a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.11 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Get along in professional dynamics: how to get along in a group and with individual**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.12 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.13 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Listen and accept instructions**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.14 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Able to give and take constructive criticism: professionalism, do not take things personally**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.15 How important is **Common sense** compared to **Good attitude?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.16 How important is **Common sense** compared to **Create a "win-win" atmosphere**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.17 How important is **Common sense** compared to **Confidence and enthusiasm**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.18 How important is **Common sense** compared to **Relevant communication skills via computers [email]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.19 How important is **Common sense** compared to **Form working relationships with a variety of people**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.20 How important is **Common sense** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.21 How important is **Common sense** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.22 How important is **Common sense** compared to **Sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.23 How important is **Common sense** compared to **Be a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.24 How important is **Common sense** compared to **Get along in professional dynamics: how to get along in a group and with individual**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.25 How important is **Common sense** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.26 How important is **Common sense** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.27 How important is **Common sense** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.28 How important is **Good attitude** compared to **Create a "win-win" atmosphere?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.29 How important is **Good attitude** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.30 How important is **Good attitude** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.31 How important is **Good attitude** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.32 How important is **Good attitude** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.33 How important is **Good attitude** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.34 How important is **Good attitude** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.35 How important is **Good attitude** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.36 How important is **Good attitude** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.37 How important is **Good attitude** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.38 How important is **Good attitude** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.39 How important is **Good attitude** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.40 How important is **Create a "win-win" atmosphere** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.41 How important is **Create a "win-win" atmosphere** compared to **Relevant communication skills via computers [email]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.42 How important is **Create a "win-win" atmosphere** compared to **Form working relationships with a variety of people**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.43 How important is **Create a "win-win" atmosphere** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.44 How important is **Create a "win-win" atmosphere** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.45 How important is **Create a "win-win" atmosphere** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.46 How important is **Create a "win-win" atmosphere** compared to **Be a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.47 How important is **Create a "win-win" atmosphere** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.48 How important is **Create a "win-win" atmosphere** compared to **Skill as a mentor: help others, foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.49 How important is **Create a "win-win" atmosphere** compared to **Listen and accept instructions**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.50 How important is **Create a "win-win" atmosphere** compared to **Able to give and take constructive criticism: professionalism, do not take things personally**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.51 How important is **Confidence and enthusiasm** compared to **Relevant communication skills via computers [email]**?

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.52 How important is **Confidence and enthusiasm** compared to **Form working relationships with a variety of people**?

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.53 How important is **Confidence and enthusiasm** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.54 How important is **Confidence and enthusiasm** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.55 How important is **Confidence and enthusiasm** compared to **Sell ideas to others?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.56 How important is **Confidence and enthusiasm** compared to **Be a team player?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.57 How important is **Confidence and enthusiasm** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.58 How important is **Confidence and enthusiasm** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.59 How important is **Confidence and enthusiasm** compared to **Listen and accept instructions?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.60 How important is **Confidence and enthusiasm** compared to? **Able to give and take constructive criticism: professionalism, do not take things personally**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.61 How important is **Relevant communication skills via computers [email]** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.62 How important is **Relevant communication skills via computers [email]** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.63 How important is **Relevant communication skills via computers [email]** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.64 How important is **Relevant communication skills via computers [email]** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.65 How important is **Relevant communication skills via computers [email]** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.66 How important is **Relevant communication skills via computers [email]** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.67 How important is **Relevant communication skills via computers [email]** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.68 How important is **Relevant communication skills via computers [email]** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.69 How important is **Relevant communication skills via computers [email]** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.70 How important is **Form working relationships with a variety of people** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.71 How important is **Form working relationships with a variety of people** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.72 How important is **Form working relationships with a variety of people** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.73 How important is **Form working relationships with a variety of people** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.74 How important is **Form working relationships with a variety of people** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.75 How important is **Form working relationships with a variety of people** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.76 How important is **Form working relationships with a variety of people** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.77 How important is **Form working relationships with a variety of people** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.78 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to? **Communicate well both orally [info, persuasive] and written [info, persuasive]**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.79 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.80 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.81 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.82 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.83 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.84 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.85 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.86 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.87 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.88 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.89 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.90 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.91 How important is **Sell ideas to others** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.92 How important is **Sell ideas to others** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.93 How important is **Sell ideas to others** compared to? **Skill as a mentor: help others, foster development beyond training**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.94 How important is **Sell ideas to others** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.95 How important is **Sell ideas to others** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.96 How important is **Be a team player** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.97 How important is **Be a team player** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.98 How important is **Be a team player** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.99 How important is **Be a team player** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.100 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.101 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.102 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.103 How important is **Skill as a mentor: help others, foster development beyond training** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.104 How important is **Skill as a mentor: help others, foster development beyond training** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.105 How important is **Listen and accept instructions** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Political

Considering the quality of Political skills, please compare the following factors and circle the number corresponding to your choice:

1.4.1 How important is **ID people & relationships in a variety of organizations as resources** compared to **Ability to convert organizational goals into source of influence: individual & teams**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.2 How important is **ID people & relationships in a variety of organizations as resources** compared to **Lack of political inclination (influence/respect vs. power)**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.3 How important is **ID people & relationships in a variety of organizations as resources** compared to **Be adaptable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.4 How important is **ID people & relationships in a variety of organizations as resources** compared to **Able to maintain valuable alliances**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.5 How important is **ID people & relationships in a variety of organizations as resources** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.6 How important is **ID people & relationships in a variety of organizations as resources** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.7 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Lack of political inclination (influence/respect vs. power**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.8 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Be adaptable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.9 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Able to maintain valuable alliances**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.10 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.11 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.12 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Be adaptable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.13 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.14 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.15 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.16 How important is **Be adaptable** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.17 How important is **Be adaptable** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.18 How important is **Be adaptable** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.19 How important is **Able to maintain valuable alliances** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.20 How important is **Able to maintain valuable alliances** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.21 How important is **Knowledge of which "fight to fight" and which one "not to fight": pick your battles** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Part 2. Understanding the Alignment of Manufacturing Needs and Engineering Graduate Students

In the space below, please write down the first five things that come to mind when you think about how close your engineering candidates currently match your company's manufacturing needs.

In the space below, please write down what you want in your engineering candidates in the future.

Considering the word "Alignment", please write down the first five things this word means to you when you read the following statement:

"Engineering schools and manufacturing must work together to have graduate students aligned to my manufacturing business requirements."

Part 2. Understanding the Alignment of Manufacturing Needs and Engineering Graduate Students

In the space below, please write down the first five things that come to mind when you think about how close your engineering candidates currently match your company's manufacturing needs.

In the space below, please write down what you want in your engineering candidates in the future.

Considering the word "Alignment", please write down the first five things this word means to you when you read the following statement:

"<u>Engineering schools and manufacturing must work together to have graduate students aligned to my manufacturing business requirements</u>."

Oklahoma State University
School of Industrial Engineering & Management

(Date)

Dear Engineering Educator,

I am David Hartmann, a doctoral candidate at Oklahoma State University. I am conducting a study of engineering outcomes from manufacturing engineering programs. The intent of the study is to determine the characteristics of the engineering student holding the graduate degree, which manufacturers desire in their engineering employees to be competitive in their respective markets. In addition the research investigates the student's characteristics alignment between academic outcome and manufacturing requirements.

To pursue this research two paths of inquiry are ongoing – academic and manufacturing. The manufacturing perceptions are complete. We now seek a consensus opinion of a select group of engineering academicians.

Your opinions, comments, and perceptions on the characteristics of the ideal engineering graduate student completing a curriculum towards an advanced degree will greatly contribute to the success of the study.

Request you identify an engineering educator generally conforming to the following specifications:

- The individual has earned the terminal Ph.D. in an engineering discipline;
- The panel member is a professional engineer as defined by the particular state's board of engineering registration in the state of their faculty assignment; and
- The panel member has been directly involved with the engineering department's business advisory committee or similar such committee.

The research project should not take any more than one hour to complete in three brief questionnaires during February 2003 – three hours total.

We have enclosed a stamped self-addressed post card on which you can indicate your preference to participate in the study.

The study has been designed in a way that you would not be asked any sensitive questions. The study will be conducted by an experienced researcher using a three step Delphi group process that will not ask for any information, which later could be traced to any particular individual in the study. It is the "group's" opinion alone that will shape the outcome of the study. A survey will be sent to the member you nominate.

Respectfully, we request your reply by 1 February 2003.

If you have any questions regarding the study, please contact David H. Hartmann at (405) 974-2839 or e-mail at dhartmann@ucok.edu.

Thank you for your interest, assistance, and cooperation.

Sincerely,

David H. Hartmann
Researcher

Encl.: (1) Reply postcard

Oklahoma State University
322 EN
Stillwater, OK 74078

INFORMED CONSENT - Academia

A. AUTHORIZATION

I,_________________, hereby authorize or direct Mr. David H. Hartmann or associates or assistants of his choosing, to perform the following treatment or procedure.

B. DESCRIPTION OF RESEARCH AND ASSOCIATED RISKS/BENEFITS

1. Research project is called: "A Process to Model Customer-Focused Engineering Program Alignment by Means of Group Consensus and Analytical Hierarchical Process Analysis".
2. This is exploratory research being conducted through Oklahoma State University by Mr. David Hartmann, Principal Investigator, doctoral student, School of Industrial Engineering and Management, OSU and Kenneth E. Case, Ph.D., doctoral advisor, School of Industrial Engineering and Management, OSU.
3. The purpose of the research is to obtain the written opinions of an expert group of academics representing engineering departments in states within and contiguous to the State of Oklahoma regarding the expected, terminal outcomes in graduate-level engineering students completing their graduate degrees. The research project will begin 28 October 2002 and conclude 31 May 2003.
4. Research participants will be asked to provide written opinions in a commonly used research process known as the "Delphi research method." The research protocol is designed to develop a consensus group opinion about ""engineering graduate candidates" in manufacturing jobs. As it is a consensus, all individual opinions will be used to form the overall group opinion. Participants will receive a follow-up mailed survey seeking their ranking the importance of data collected. Participants will not be asked to identify themselves on any documentation, except for the initial agreement to participate, which will be kept for the purpose of the correct spelling of participants and for mailing of the future survey. Commercially or academically proprietary information are not required or solicited in this research. It is not necessary that participants know the identities of the other participants and Mr. Hartmann will not share this information.
5. None of the procedures used in the project are experimental.
6. There are no intentional physical risks or discomfort to the participants.
7. The research participants should not expect any direct benefits from the research.
8. In this research, there are no known alternative data collection methods, which could replace the Delphi research method and written surveys.
9. Mr. Hartmann will keep the names of the participants obtained from the sign in roster and all data collected confidential and secured in a locked file cabinet in its original form or as computer data diskettes.
10. This research does not foresee any risk beyond minimal risk expected in daily life answering a questionnaire.
11. Whom to contact about the research: Mr. David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu, or postal address: D. H. Hartmann, 2801 Sweetbriar, Edmond, OK 73034.
12. Whom to contact about research subjects rights (the Oklahoma State University, Institutional Review Board, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700)
13. Additional contact: Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the principal investigator:

David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu,

or postal address: D. H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

D. CONSENT DOCUMENTATION FOR WRITTEN INFORMED CONSENT

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ______________________________ Time: ___________________________ (a.m./p.m.)

Name (typed) Signature

Signature of person authorized to sign for subject, if required

Witness(es) if required: **Not / Required**

Not / Required

I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Signed:

Principal Investigator

Academic Outcomes Questionnaire

Hello. This brief questionnaire asks you for your opinion about the desirable outcomes in the graduate engineering student you educate for employment in a manufacturing setting.

In the first part, you will be asked about a general classification of graduate manufacturing engineering program outcomes.

In the second part, you will be asked about alignment of manufacturing needs and program outcomes.

In a future mailing, you will be asked to consider the opinions of other engineering educators so that the respondent group will approach a consensus on the desirable outcomes for a graduate manufacturing engineer.

We thank you very much for your valuable time and promise to make this survey very brief. Remember, this survey is entirely confidential. Your name will not appear on the data collected and you will not be identified to other participants in this study.

If you have any questions about this survey, please call the Principal Investigator, Dave Hartmann, at (405) 359-3995, or use the e-mails at Dhartm0669@aol.com.

I would be very happy to assist you in any way to better understand this survey.

Part 1. Graduate Manufacturing Engineering Outcomes

In the space below, please write down as many outcomes as possible, which should result in every engineering graduate student. Please attach additional sheets, if required.

Please attempt to classify the outcomes you identified under general headings, such as theory, practice, ethics, communicative skills, etc. Please attach additional sheets, if required.

Part 2. Understanding the Alignment of Manufacturing Needs and Engineering Graduate Students

In the space below, please write down the first five things that come to mind when you think about how close your engineering candidates currently match contemporary manufacturing company's engineering needs.

In the space below, please write down what you want in your engineering graduates in the role of candidates for manufacturing engineering employment.

Considering the word "Alignment", please write down the first five things this word means to you when you read the following statement:

"Engineering schools and manufacturing must work together to have graduate students aligned to my manufacturing business requirements."

Technical

Science & math background
Application of the basics
Technical expert in particular field [skill]
Able to define the problem – problem solving overall
Able to analyze using specific tools – economic engineering, risk analysis
Computer literate
Knowledge of industry standards
Able to sell ideas to others
ISO 9002
Failure analysis techniques
Be trainable
Hands on experience -- internships/co-ops
Hands on experience -- machining, lathe, milling @ vo-tech
Did you have "real world" experience b/w degrees?

Managerial

Problem solving skills: breaking down into smaller elements
Able to analyze (i.e. engineering economics)
Plan a project, manage projects and budget estimates
Understand lean management in an overall environment
Understand the difference between repair and new manufacturing
Self-motivated
Seeks challenges/new ideas
Be able to chair meetings [plan & direct]
Multi-tasking [good time management]
Smoothly transition roles as a leader and a team player
Be trainable
Skill as a mentor: help others/foster development beyond training

Political

ID people & relationships in a variety of organizations as resources
Ability to convert organizational goals into source of influence: individual & teams
Lack of political inclination (influence/respect vs. power)
Be adaptable
Able to maintain valuable alliances
Knowledge of which "fight to fight" and which one "not to fight": pick your battles
Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")

Social	
	Good communication skills: able to switch gears and direct communication appropriately – change in audience
	Common sense
	Good attitude
	Create a "win-win" atmosphere
	Confidence and enthusiasm
	Relevant communication skills via computers [email]
	Form working relationships with a variety of people
	Aware and willing to "earn" respect in a manufacturing environment
	Communicate well both orally [info, persuasive] and written [info, persuasive]
	Sell ideas to others
	Be a team player
	Get along in professional dynamics: how to get along in a group and with individual
	Skill as a mentor: help others, foster development beyond training
	Listen and accept instructions
	Able to give and take constructive criticism: professionalism, do not take things personally

Working Definitions

Social Competence: The ability to work with, understand, communicate with and motivate other people, both individually and in groups.

Political: Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.

Managerial: Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Technical skills: Specialized knowledge and expertise used to carry out particular techniques or procedures.

Oklahoma State University
322 EN
Stillwater, OK 74078

INFORMED CONSENT - Academia

A. AUTHORIZATION

I,___________________, hereby authorize or direct Mr. David H. Hartmann or associates or assistants of his choosing, to perform the following treatment or procedure.

B. DESCRIPTION OF RESEARCH AND ASSOCIATED RISKS/BENEFITS

1. Research project is called: "A Process to Model Customer-Focused Engineering Program Alignment by Means of Group Consensus and Analytical Hierarchical Process Analysis".
2. This is exploratory research being conducted through Oklahoma State University by Mr. David Hartmann, Principal Investigator, doctoral student, School of Industrial Engineering and Management, OSU and Kenneth E. Case, Ph.D., doctoral advisor, School of Industrial Engineering and Management, OSU.
3. The purpose of the research is to obtain the written opinions of an expert group of academics representing engineering departments in states within and contiguous to the State of Oklahoma regarding the expected, terminal outcomes in graduate-level engineering students completing their graduate degrees. The research project will begin 28 October 2002 and conclude 31 May 2003.
4. Research participants will be asked to provide written opinions in a commonly used research process known as the "Delphi research method." The research protocol is designed to develop a consensus group opinion about ""engineering graduate candidates" in manufacturing jobs. As it is a consensus, all individual opinions will be used to form the overall group opinion. Participants will receive a follow-up mailed survey seeking their ranking the importance of data collected. Participants will not be asked to identify themselves on any documentation, except for the initial agreement to participate, which will be kept for the purpose of the correct spelling of participants and for mailing of the future survey. Commercially or academically proprietary information are not required or solicited in this research. It is not necessary that participants know the identities of the other participants and Mr. Hartmann will not share this information.
5. None of the procedures used in the project are experimental.
6. There are no intentional physical risks or discomfort to the participants.
7. The research participants should not expect any direct benefits from the research.
8. In this research, there are no known alternative data collection methods, which could replace the Delphi research method and written surveys.
9. Mr. Hartmann will keep the names of the participants obtained from the sign in roster and all data collected confidential and secured in a locked file cabinet in its original form or as computer data diskettes.
10. This research does not foresee any risk beyond minimal risk expected in daily life answering a questionnaire.
11. Whom to contact about the research: Mr. David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu, or postal address: D. H. Hartmann, 2801 Sweetbriar, Edmond, OK 73034.
12. Whom to contact about research subjects rights (the Oklahoma State University, Institutional Review Board, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700)
13. Additional contact: Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the principal investigator:

David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu,

or postal address: D. H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

D. CONSENT DOCUMENTATION FOR WRITTEN INFORMED CONSENT

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ______________________________ Time: ___________________________ (a.m./p.m.)

Name (typed) Signature

Signature of person authorized to sign for subject, if required

Witness(es) if required: **Not / Required**

Not / Required

I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Signed:

Principal Investigator

Technical

Science & math background
Application of the basics
Technical expert in particular field [skill]
Able to define the problem – problem solving overall
Able to analyze using specific tools – economic engineering, risk analysis
Computer literate
Knowledge of industry standards
Able to sell ideas to others
ISO 9002
Failure analysis techniques
Be trainable
Hands on experience -- internships/co-ops
Hands on experience -- machining, lathe, milling @ vo-tech
Did you have "real world" experience b/w degrees?

Managerial

Problem solving skills: breaking down into smaller elements
Able to analyze (i.e. engineering economics)
Plan a project, manage projects and budget estimates
Understand lean management in an overall environment
Understand the difference between repair and new manufacturing
Self-motivated
Seeks challenges/new ideas
Be able to chair meetings [plan & direct]
Multi-tasking [good time management]
Smoothly transition roles as a leader and a team player
Be trainable
Skill as a mentor: help others/foster development beyond training

Political

LEADERSHIP / POWER

ID people & relationships in a variety of organizations as resources
Ability to convert organizational goals into source of influence: individual & teams
Lack of political inclination (influence/respect vs. power)
Be adaptable
Able to maintain valuable alliances
Knowledge of which "fight to fight" and which one "not to fight": pick your battles
Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")

Social	
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience
	Common sense
	Good attitude
	Create a "win-win" atmosphere
	Confidence and enthusiasm
	Relevant communication skills via computers [email]
	Form working relationships with a variety of people
	Aware and willing to "earn" respect in a manufacturing environment
	Communicate well both orally [info, persuasive] and written [info, persuasive]
	Sell ideas to others
	Be a team player
	Get along in professional dynamics: how to get along in a group and with individual
	Skill as a mentor: help others, foster development beyond training
	Listen and accept instructions
	Able to give and take constructive criticism: professionalism, do not take things personally

Working Definitions

Social Competence: The ability to work with, understand, communicate with and motivate other people, both individually and in groups.

Political: Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.

Managerial: Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Technical skills: Specialized knowledge and expertise used to carry out particular techniques or procedures.

[Date]

Dear [name]:

Hello. This is a follow-up letter and survey resulting from our research meeting held in mid-December. As you may recall, the research group was asked to comment upon **the ideal characteristics of a graduate engineer candidate competing for a position in your unit.**

In **Part 1** of the survey, you will be asked to make judgments about the topics your team developed during the research meeting, December 18, 2002, Tinker AFB, OK. The attached questionnaire uses the factors the group agreed upon as relevant to the candidate in the areas of Management, Social, Political, and Social skills. This part should take about 60 minutes to complete.

In **Part 2**, you will be asked about a number of topics that the colleges of engineering try very hard to develop in their graduates. Your opinions are an extremely valuable help in the colleges having the right courses, practical exercises, and field experiences needed to make the best graduate for today's business community. This part should take about 30 minutes to complete.

We thank you very much for your valuable time. Remember, this survey is entirely confidential. Your name will not appear on the data collected.

Please enclose your surveys into the enclosed, self-addressed stamped envelope. We ask that you return the completed surveys by 31 January 2003.

If you have any questions about this survey, please call me, Dave Hartmann, at (405) 359-3995 or e-mail Dhartm0669@aol.com.

I would be very happy to assist you in any way to better understand this survey.

Respectfully,

David H. Hartmann
Principal Investigator

Encl.: (xx)

Industrial Requirements Survey

This survey follows up on the research conducted in mid-December 2002. It asks you to comparatively judge between an engineering candidate's knowledge, skills or competencies [factors]. Assume that these factors are gained through a graduate engineering education program. Further, assume the candidate is competing for a job in your unit.

In this survey, you will make comparative judgments between engineering factors on a scale ranging from "extremely more important" to "extremely less important". For simplicity, we will represent these judgments using the numerals "plus 9" to a "minus 9" in single digit increments, for example, 9, 8, 7...-7, -8, & -9. The numeral 1 is the midpoint and represents factors of about the same level of importance. For example, comparing a factor to itself would result in a judgment of "1".

Let's look at a commonplace example facing ordinary consumers – "purchasing a new car."

Several "factors" you could use to choose one vehicle over another might be **price, available options, standard equipment**, and so on. While each factor is important for making a final "best" decision, however, in comparing them side-by-side one factor might be more or less important than another factor. So, let's compare just **price** and **standard equipment**.

Example question #1.
"When buying a new car or truck, ***price*** is (how important) compared to ***standard features***?"

1	+2	+3	+4	+5	+6	+7	+8	+9
About the same		Slightly more important		Strongly more important		Very strongly more important		Extremely more important

1	-2	-3	-4	-5	-6	-7	-8	-9
About the same		Slightly less important		Strongly less important		Very strongly less important		Extremely less important

Please circle the number above which states your judgment about how important ***price*** is to ***standard features***.

Now, using the same rankings as, ***Example question #1,*** but removing the text:

Example question #2.
"When buying a new car or truck, ***price*** is (how important) compared to ***available options***?" Circle your judgment.

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Part 1, "Industrial Requirements Survey" will resemble example question #2. Please use pencil to mark your answers. There are no "right answers". However, if you want to change your answer, completely erase your first response and mark your revised judgment.

Thank you for your valuable time completing this survey.

Part 1. Managerial, Technical, Social, and Political Factors

Consider the relative importance of ***management, technical, social,*** and ***political*** factors. Then using the **+9 [Plus Nine]** to **–9 [Minus Nine]** judgment scales previously described, please compare the following factors and circle one number corresponding to your judgment. The factors your research team agreed upon as part of the candidate engineer's background are shown in **bold print**.

"Given you want to employ the most qualified engineering graduate degree candidate."

1.1 How important is **Managerial** compared to **Technical**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2 How important is **Managerial** compared to **Social**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3 How important is **Managerial** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4 How important is **Technical** compared to **Social**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.5 How important is **Technical** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.6 How important is **Social** compared to **Political**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Managerial

Consider the engineering factor – **Managerial**. Please compare the following factors and circle one number corresponding to your choice:

1.1.1 How important is **Problem solving skills: breaking down into smaller elements** compared to **Able to analyze (i.e. engineering economics)**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.2 How important is **Problem solving skills: breaking down into smaller elements** compared to **Plan a project, manage projects and budget estimates**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.3 How important is **Problem solving skills: breaking down into smaller elements** compared to **Understand lean management in an overall environment**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.4 How important is **Problem solving skills: breaking down into smaller elements** compared to **Understand the difference between repair and new manufacturing**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.5 How important is **Problem solving skills: breaking down into smaller elements** compared to **Self-motivate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.6 How important is **Problem solving skills: breaking down into smaller elements** compared to **Seek challenges/new ideas**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.7 How important is **Problem solving skills: breaking down into smaller elements** compared to be **Able to chair meetings [plan & direct]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.8 How important is **Problem solving skills: breaking down into smaller elements** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.9 How important is **Problem solving skills: breaking down into smaller elements** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.10 How important is **Problem solving skills: breaking down into smaller elements** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.11 How important is **Problem solving skills: breaking down into smaller elements** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.12 How important is **Able to analyze (i.e. engineering economics)** compared to **Plan a project, manage projects and budget estimates**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.13 How important is **Able to analyze (i.e. engineering economics)** compared to **Understand lean management in an overall environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.14 How important is **Able to analyze (i.e. engineering economics)** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.15 How important is **Able to analyze (i.e. engineering economics)** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.16 How important is **Able to analyze (i.e. engineering economics)** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.17 How important is **Able to analyze (i.e. engineering economics)** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.18 How important is **Able to analyze (i.e. engineering economics)** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.19 How important is **Able to analyze (i.e. engineering economics)** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.20 How important is **Able to analyze (i.e. engineering economics)** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.21 How important is **Able to analyze (i.e. engineering economics)** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.22 How important is **Plan a project, manage projects and budget estimates** compared to **Understand lean management in an overall environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.23 How important is **Plan a project, manage projects and budget estimates** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.24 How important is **Plan a project, manage projects and budget estimates** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.25 How important is **Plan a project, manage projects and budget estimates** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.26 How important is **Plan a project, manage projects and budget estimates** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.27 How important is **Plan a project, manage projects and budget estimates** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.28 How important is **Plan a project, manage projects and budget estimates** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.29 How important is **Plan a project, manage projects and budget estimates** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.30 How important is **Plan a project, manage projects and budget estimates** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.31 How important is **Understand lean management in an overall environment** compared to **Understand the difference between repair and new manufacturing?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.32 How important is **Understand lean management in an overall environment** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.33 How important is **Understand lean management in an overall environment** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.34 How important is **Understand lean management in an overall environment** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.35 How important is **Understand lean management in an overall environment** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.36 How important is **Understand lean management in an overall environment** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.37 How important is **Understand lean management in an overall environment** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.38 How important is **Understand lean management in an overall environment** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.39 How important is **Understand the difference between repair and new manufacturing** compared to **Self-motivate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.40 How important is **Understand the difference between repair and new manufacturing** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.41 How important is **Understand the difference between repair and new manufacturing** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.42 How important is **Understand the difference between repair and new manufacturing** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.43 How important is **Understand the difference between repair and new manufacturing** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.44 How important is **Understand the difference between repair and new manufacturing** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.45 How important is **Understand the difference between repair and new manufacturing** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.46 How important is **Self-motivate** compared to **Seek challenges/new ideas?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.47 How important is **Self-motivate** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.48 How important is **Self-motivate** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.49 How important is **Self-motivate** compared to **Smoothly transition roles as a leader and a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.50 How important is **Self-motivate** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.51 How important is **Self-motivate** compared to **Skill as a mentor: help others/foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.52 How important is **Seek challenges/new ideas** compared to **Able to chair meetings [plan & direct]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.53 How important is **Seek challenges/new ideas** compared to **Multi-tasking [good time management]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.54 How important is **Seek challenges/new ideas** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.55 How important is **Seek challenges/new ideas** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.56 How important is **Seek challenges/new ideas** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.57 How important is **Able to chair meetings [plan & direct]** compared to **Multi-tasking [good time management]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.58 How important is **Able to chair meetings [plan & direct]** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.59 How important is **Able to chair meetings [plan & direct]** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.60 How important is **Able to chair meetings [plan & direct]** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.61 How important is **Multi-tasking [good time management]** compared to **Smoothly transition roles as a leader and a team player**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.62 How important is **Multi-tasking [good time management]** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.63 How important is **Multi-tasking [good time management]** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.64 How important is **Smoothly transition roles as a leader and a team player** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.65 How important is **Smoothly transition roles as a leader and a team player** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.1.66 How important is **Be trainable** compared to **Skill as a mentor: help others/foster development beyond training**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Technical

Consider the engineering factor -- **Technical**, please compare the following factors and circle the number corresponding to your choice:

1.2.1 How important is **Science & math background** compared to **Application of the basics**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.2 How important is **Science & math background** compared to **Technical expert in particular field [skill]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.3 How important is **Science & math background** compared to **Able to define the problem – problem solving overall?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.4 How important is **Science & math background** compared to **Able to analyze using specific tools – economic engineering, risk analysis?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.5 How important is **Science & math background** compared to **Computer literate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.6 How important is **Science & math background** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.7 How important is **Science & math background** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.8 How important is **Science & math background** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.9 How important is **Science & math background** compared **to Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.10 How important is **Science & math background** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.11 How important is **Science & math background** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.12 How important is **Science & math background** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.13 How important is **Science & math background** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.14 How important is **Application of the basics** compared to **Technical expert in particular field [skill]**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.15 How important is **Application of the basics** compared to **Able to define the problem – problem solving overall**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.16 How important is **Application of the basics** compared to **Able to analyze using specific tools – economic engineering, risk analysis**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.17 How important is **Application of the basics** compared to **Computer literate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.18 How important is **Application of the basics** compared to **Knowledge of industry standards**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.19 How important is **Application of the basics** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.20 How important is **Application of the basics** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.21 How important is **Application of the basics** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.22 How important is **Application of the basics** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.23 How important is **Application of the basics** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.24 How important is **Application of the basics** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.25 How important is **Application of the basics** compared to **Did you have "real world" experience b/w degrees**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.26 How important is **Technical expert in particular field [skill** compared to **Able to define the problem – problem solving overall**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.27 How important is **Technical expert in particular field [skill** compared to **Able to analyze using specific tools – economic engineering, risk analysis**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.28 How important is **Technical expert in particular field [skill** compared to **Computer literate**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.29 How important is **Technical expert in particular field [skill** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.30 How important is **Technical expert in particular field [skill** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.31 How important is **Technical expert in particular field [skill** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.32 How important is **Technical expert in particular field [skill** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.33 How important is **Technical expert in particular field [skill** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.34 How important is **Technical expert in particular field [skill** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.35 How important is **Technical expert in particular field [skill** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.36 How important is **Technical expert in particular field [skill** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.37 How important is **Able to define the problem – problem solving overall** compared to **Able to analyze using specific tools – economic engineering, risk analysis?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.38 How important is **Able to define the problem – problem solving overall** compared to **Computer literate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.39 How important is **Able to define the problem – problem solving overall** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.40 How important is **Able to define the problem – problem solving overall** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.41 How important is **Able to define the problem – problem solving overall** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.42 How important is **Able to define the problem – problem solving overall** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.43 How important is **Able to define the problem – problem solving overall** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.44 How important is **Able to define the problem – problem solving overall** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.45 How important is **Able to define the problem – problem solving overall** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.46 How important is **Able to define the problem – problem solving overall** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.47 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Computer literate?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.48 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Knowledge of industry standards?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.49 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Able to sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.50 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.51 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Failure analysis techniques?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.52 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Be trainable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.53 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.54 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.55 How important is **Able to analyze using specific tools – economic engineering, risk analysis** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.56 How important is **Computer literate** compared to **Knowledge of industry standards**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.57 How important is **Computer literate** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.58 How important is **Computer literate** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.59 How important is **Computer literate** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.60 How important is **Computer literate** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.61 How important is **Computer literate** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.62 How important is **Computer literate** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.63 How important is **Computer literate** compared to **Did you have "real world" experience b/w degrees?**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.64 How important is **Knowledge of industry standards** compared to **Able to sell ideas to others**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.65 How important is **Knowledge of industry standards** compared to **ISO 9002?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.66 How important is **Knowledge of industry standards** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.67 How important is **Knowledge of industry standards** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.68 How important is **Knowledge of industry standards** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.69 How important is **Knowledge of industry standards** compared to **Hands on experience – machining, lathe, milling @ vo-tech**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.70 How important is **Knowledge of industry standards** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.71 How important is **Able to sell ideas to others** compared to **ISO 9002**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.72 How important is **Able to sell ideas to others** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.73 How important is **Able to sell ideas to others** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.74 How important is **Able to sell ideas to others** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.75 How important is **Able to sell ideas to others** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.76 How important is **Able to sell ideas to others** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.77 How important is **ISO 9002** compared to **Failure analysis techniques**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.78 How important is **ISO 9002** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.79 How important is **ISO 9002** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.80 How important is **ISO 9002** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.81 How important is **ISO 9002** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.82 How important is **Failure analysis techniques** compared to **Be trainable**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.83 How important is **Failure analysis techniques** compared to **Hands on experience – internships/co-ops**?

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.84 How important is **Failure analysis techniques** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.85 How important is **Failure analysis techniques** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.86 How important is **Be trainable** compared to **Hands on experience – internships/co-ops?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.87 How important is **Be trainable** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.88 How important is **Be trainable** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.89 How important is **Hands on experience – internships/co-ops** compared to **Hands on experience – machining, lathe, milling @ vo-tech?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.90 How important is **Hands on experience – internships/co-ops** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.2.91 How important is **Hands on experience – machining, lathe, milling @ vo-tech** compared to **Did you have "real world" experience b/w degrees?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Social

Considering the engineering factor: **Social**, please compare the following factors and circle the number corresponding to your choice:

1.3.1 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Common sense?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.2 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Good attitude?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.3 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Create a "win-win" atmosphere?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.4 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.5 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.6 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.7 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.8 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.9 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.10 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.11 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.12 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.13 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.14 How important is **Good communication skills: able to switch gears and direct communication appropriately – change in audience** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.15 How important is **Common sense** compared to **Good attitude?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.16 How important is **Common sense** compared to **Create a "win-win" atmosphere?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.17 How important is **Common sense** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.18 How important is **Common sense** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.19 How important is **Common sense** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.20 How important is **Common sense** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.21 How important is **Common sense** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.22 How important is **Common sense** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.23 How important is **Common sense** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.24 How important is **Common sense** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.25 How important is **Common sense** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.26 How important is **Common sense** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.27 How important is **Common sense** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.28 How important is **Good attitude** compared to **Create a "win-win" atmosphere?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.29 How important is **Good attitude** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.30 How important is **Good attitude** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.31 How important is **Good attitude** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.32 How important is **Good attitude** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.33 How important is **Good attitude** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.34 How important is **Good attitude** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.35 How important is **Good attitude** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.36 How important is **Good attitude** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.37 How important is **Good attitude** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.38 How important is **Good attitude** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.39 How important is **Good attitude** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.40 How important is **Create a "win-win" atmosphere** compared to **Confidence and enthusiasm?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.41 How important is **Create a "win-win" atmosphere** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.42 How important is **Create a "win-win" atmosphere** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.43 How important is **Create a "win-win" atmosphere** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.44 How important is **Create a "win-win" atmosphere** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.45 How important is **Create a "win-win" atmosphere** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.46 How important is **Create a "win-win" atmosphere** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.47 How important is **Create a "win-win" atmosphere** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.48 How important is **Create a "win-win" atmosphere** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.49 How important is **Create a "win-win" atmosphere** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.50 How important is **Create a "win-win" atmosphere** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.51 How important is **Confidence and enthusiasm** compared to **Relevant communication skills via computers [email]?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.52 How important is **Confidence and enthusiasm** compared to **Form working relationships with a variety of people?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.53 How important is **Confidence and enthusiasm** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.54 How important is **Confidence and enthusiasm** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.55 How important is **Confidence and enthusiasm** compared to **Sell ideas to others?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.56 How important is **Confidence and enthusiasm** compared to **Be a team player?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.57 How important is **Confidence and enthusiasm** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.58 How important is **Confidence and enthusiasm** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.59 How important is **Confidence and enthusiasm** compared to **Listen and accept instructions?**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.60 How important is **Confidence and enthusiasm** compared to? **Able to give and take constructive criticism: professionalism, do not take things personally**

9	8	7	6	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.61 How important is **Relevant communication skills via computers [email]** compared to **Form working relationships with a variety of people?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.62 How important is **Relevant communication skills via computers [email]** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.63 How important is **Relevant communication skills via computers [email]** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.64 How important is **Relevant communication skills via computers [email]** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.65 How important is **Relevant communication skills via computers [email]** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.66 How important is **Relevant communication skills via computers [email]** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.67 How important is **Relevant communication skills via computers [email]** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.68 How important is **Relevant communication skills via computers [email]** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.69 How important is **Relevant communication skills via computers [email]** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.70 How important is **Form working relationships with a variety of people** compared to **Aware and willing to "earn" respect in a manufacturing environment?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.71 How important is **Form working relationships with a variety of people** compared to **Communicate well both orally [info, persuasive] and written [info, persuasive]?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.72 How important is **Form working relationships with a variety of people** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.73 How important is **Form working relationships with a variety of people** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.74 How important is **Form working relationships with a variety of people** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.75 How important is **Form working relationships with a variety of people** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.76 How important is **Form working relationships with a variety of people** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.77 How important is **Form working relationships with a variety of people** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.78 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to? **Communicate well both orally [info, persuasive] and written [info, persuasive]**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.79 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.80 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.81 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.82 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.83 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.84 How important is **Aware and willing to "earn" respect in a manufacturing environment** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.85 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Sell ideas to others?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.86 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Be a team player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.87 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.88 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.89 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.90 How important is **Communicate well both orally [info, persuasive] and written [info, persuasive]** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.91 How important is **Sell ideas to others** compared to **Be a team-player?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.92 How important is **Sell ideas to others** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.93 How important is **Sell ideas to others** compared to? **Skill as a mentor: help others, foster development beyond training**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.94 How important is **Sell ideas to others** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.95 How important is **Sell ideas to others** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.96 How important is **Be a team player** compared to **Get along in professional dynamics: how to get along in a group and with individual?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.97 How important is **Be a team player** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.98 How important is **Be a team player** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.99 How important is **Be a team player** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.100 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Skill as a mentor: help others, foster development beyond training?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.101 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.102 How important is **Get along in professional dynamics: how to get along in a group and with individual** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.103 How important is **Skill as a mentor: help others, foster development beyond training** compared to **Listen and accept instructions?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.104 How important is **Skill as a mentor: help others, foster development beyond training** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.3.105 How important is **Listen and accept instructions** compared to **Able to give and take constructive criticism: professionalism, do not take things personally?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Political

Considering the quality of Political skills, please compare the following factors and circle the number corresponding to your choice:

1.4.1 How important is **ID people & relationships in a variety of organizations as resources** compared to **Ability to convert organizational goals into source of influence: individual & teams?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.2 How important is **ID people & relationships in a variety of organizations as resources** compared to **Lack of political inclination (influence/respect vs. power)?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.3 How important is **ID people & relationships in a variety of organizations as resources** compared to **Be adaptable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.4 How important is **ID people & relationships in a variety of organizations as resources** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.5 How important is **ID people & relationships in a variety of organizations as resources** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.6 How important is **ID people & relationships in a variety of organizations as resources** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.7 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Lack of political inclination (influence/respect vs. power?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.8 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Be adaptable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.9 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.10 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.11 How important is **Ability to convert organizational goals into source of influence: individual & teams** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.12 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Be adaptable?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.13 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.14 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.15 How important is **Lack of political inclination (influence/respect vs. power)** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.16 How important is **Be adaptable** compared to **Able to maintain valuable alliances?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.17 How important is **Be adaptable** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.18 How important is **Be adaptable** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.19 How important is **Able to maintain valuable alliances** compared to **Knowledge of which "fight to fight" and which one "not to fight": pick your battles?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.20 How important is **Able to maintain valuable alliances** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

1.4.21 How important is **Knowledge of which "fight to fight" and which one "not to fight": pick your battles** compared to **Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")?**

9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9

Appendix 6 - Phase III Pretest

With change(s) or references.

David H. Hartmann
2801 Sweetbriar
Edmond, Oklahoma 73034-6554
Dhartm0669@aol.com

February 23, 2003

["Participant"]
OC-ALC/XXXXX
3001 Staff Drive
Tinker Air Force Base, Oklahoma 73145-3001

Dear ["Participant"]:

Thank you very much for your participation in the Oklahoma City Air Logistics Center and the School of Industrial Engineering & Management, Oklahoma State University study of Oklahoma manufacturers. As you may recall, the intent of the study is to determine what manufacturers need in their graduate engineering employees that could be provided by college and university engineering programs to help the manufacturers be more competitive. This letter is a status report and the introduction of Phase 2 of the research project – the phase where I need your help very much.

Phase 1. This phase was completed late December 2002. To recap – four ideas motivated the team's brainstorming a set of graduate engineering criteria: *technical, managerial, social,* and *political* criteria [Tab 1]. Our research team then developed a "consensus of research findings", which the team grouped under one of those four criteria [Tab 2].

Phase 2. As briefed in December, the research project proposed to use a decision-analysis tool known in statistical research as "analytical hierarchy processes" [AHP]. AHP takes a problem and breaks-down the decisions resolving the problem into subordinate parts. In a way, this model resembles a multi-level building, where the top floor is the desired outcome of the decisions and is called Level "0"; the next level down is "Level 1"; and so forth. In this research project, Level 0 is the "ideal graduate engineering candidate."

["Participant"], since the December team meeting, I arbitrarily labeled the *technical, managerial, social,* and *political* criteria as **Level 1**. I also labeled our "consensus of research findings" – **Level 2**.

In phase 2, we request you review the **Level 1** and **Level 2** data and to provide feedback. Your feedback is very important, because it will be used to build a questionnaire to assess the importance of the criteria manufacturers need in their engineering employees.

The enclosed package contains the background and findings from the December meeting (Tabs 1 and 2). It also provides additional information for your review (Tabs 3 & 4).

Team -- Here's what we need to do in Phase 2:

- Tab 1: Provided for your information are the original findings transcribed from the charts completed during the December meeting. **No comment is requested here**.
- Tab 2: Provided FYI are the original definitions for the *technical, managerial, political,* and *social* criteria.

  NOTE: **If you wish to comment on the original definitions, an area is blocked out for you to propose changes. Please leave blank, if you are satisfied with the given definitions.**

- Tab 3: Provided are December's *technical, managerial, social,* and *political* criteria (shown under the column label **"Level 1"**); the team's consensus, grouped findings (shown as **"Level 2"**). Also shown are proposed definitions for the Level 2 criteria. This proposal is based upon the oral comments made by the participants as understood by the researcher and his assistant.

  NOTE: **Using the original Level 1 definitions (Tab 2), please review these proposed definitions and make any needed changes directly upon the page – continue onto the back of the page(s) as necessary. If satisfied a definition is appropriate, continue with your review.**

- Tab 4: Note the columns labeled Level 3, Level 4, Delete, and Reason(s) for Change. Then using the given **"Level 1"** and **"Level 2"** criteria, please make the following three assessments:

  ⇨ In a given level 1 area [technical, managerial, social, political], if a level 2 criterion appears to be subordinate to another criterion, and should be changed to level 3 or level 4, **then signify your selection by placing check mark or "X" besides it, and indicate "reasons for change"**;

  Or

  ⇨ In a given level 1 area, if level 2 criterion should be eliminated, because it is already included, unneeded, etc., **please place a check mark or "X" besides it, and indicate "reasons for change"**;

  Or

  ⇨ If a level 2 criterion should be moved under another Level 1 area, then **indicate this change under "Reason(s) for Change"**.

Your continued voluntary participation is essential to the success of the research.

["Participant"], I request you complete the review and return your package by 3 March 2003. A self-addressed stamped envelope is included for your convenience.

Should you have any questions regarding Phase 2 or any other questions concerning the Project please contact me, the principle investigator, at 405-974-2839 or via email at dhartmann@ucok.edu as soon as possible.

I am very grateful for your interest, assistance, and cooperation.

Respectfully,

David H. Hartmann
Principal Investigator

Encl.: (1)

CC: Wayne Jones, Ph.D.,
Each team member,
Kenneth Case, Ph.D.

Technical

Science & math background
Application of the basics
Technical expert in particular field [skill]
Able to define the problem – problem solving overall
Able to analyze using specific tools – economic engineering, risk analysis
Computer literate
Knowledge of industry standards
Able to sell ideas to others
ISO 9002
Failure analysis techniques
Be trainable
Hands on experience – internships/co-ops
Hands on experience – machining, lathe, milling @ vo-tech
Did you have "real world" experience b/w degrees?

Managerial

Problem solving skills: breaking down into smaller elements
Able to analyze (i.e. engineering economics)
Plan a project, manage projects and budget estimates
Understand lean management in an overall environment
Understand the difference between repair and new manufacturing
Self-motivated
Seeks challenges/new ideas
Be able to chair meetings [plan & direct]
Multi-tasking [good time management]
Smoothly transition roles as a leader and a team player
Be trainable
Skill as a mentor: help others/foster development beyond training

Political

ID people & relationships in a variety of organizations as resources
Ability to convert organizational goals into source of influence: individual & teams
Lack of political inclination (influence/respect vs. power)
Be adaptable
Able to maintain valuable alliances
Knowledge of which "fight to fight" and which one "not to fight": pick your battles
Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")

Social	
	Good communication skills: able to switch gears and direct communication appropriately – change in audience
	Common sense
	Good attitude
	Create a "win-win" atmosphere
	Confidence and enthusiasm
	Relevant communication skills via computers [email]
	Form working relationships with a variety of people
	Aware and willing to "earn" respect in a manufacturing environment
	Communicate well both orally [info, persuasive] and written [info, persuasive]
	Sell ideas to others
	Be a team player
	Get along in professional dynamics: how to get along in a group and with individual
	Skill as a mentor: help others, foster development beyond training
	Listen and accept instructions
	Able to give and take constructive criticism: professionalism, do not take things personally

Working Definitions

Social Competence: <u>The ability to work with, understand, communicate with and motivate other people, both individually and in groups</u>. Comments or changes recommended:

Political: <u>Ability to enhance his or her power, build a power base, and establish "right" connections in the organization</u>. Comments or changes recommended:

Managerial: Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Comments or changes recommended:

Technical skills: Specialized knowledge and expertise used to carry out particular techniques or procedures.

Comments or changes recommended:

Level 1	Level 2	Definition of Level 2 Engineering Factor
Technical	Science & math background	Received college-level academic credit for science and mathematics
3	Application of the basics	Has practical evidence of using science, math, and engineering in practice
3	Technical expert in particular field [skill]	Academic credit received for more than one course in subject area @ graduate level
5	Able to define the problem – problem solving overall	Able to show evidence of using a scientific method
5	Able to analyze using specific tools – economic engineering, risk analysis	Able to use engineering formulae and processes basic to project management
5	Computer literate	Demonstrated practice in use of basic computer tools such as word processing, spreadsheet, and computer-assisted engineering tools
3	Knowledge of industry standards	Is familiar with standards used in the industry, not including international standards such as ISO.
	Able to sell ideas to others	Demonstrated experience as product or process champion
3, 5	ISO 9002	Demonstrated familiarity with ISO 9002
3	Failure analysis techniques	Familiar with FMEA Failure Mode and Effects Analysis
3, 5	Be trainable	Demonstrated completion of processes designed to improve technical competence in non-academic credit awarding courses.
EXPERIENCE	Hands-on experience -- internships/co-ops	Completed an internship or co-op experience
3	Hands on experience -- machining, lathe, milling @ vo-tech [illegible] @ W-TCH	Demonstrated experience in basic machining skills
3	Did you have "real world" experience b/w degrees?	Following undergraduate degree, does the candidate have practical work experience?

263

Level 1	Level 2	Definition of Level 2 Engineering Factor
Managerial	Problem solving skills: breaking down into smaller elements	Evidence of using scientific method
	Able to analyze (i.e. engineering economics)	Able to use methodological basic engineering formulae
	Plan a project, manage projects and budget estimates	Knowledgeable and demonstrate practical experience in project management skills
	~~Understand lean management in an overall environment~~	Knowledgeable of "lean manufacturing"
	Understand the difference between repair and new manufacturing	[Self-explanatory] Asset – driven and or raw material
	Self-motivated	Works without supervisory oversight in most endeavors
	~~Seeks challenges/new ideas~~	Demonstrates experience and interest in jobs requiring data or opinion beyond the candidate's close work unit.
	~~Be able to chair meetings (plan & direct)~~	Able to develop meeting agenda, run meetings, and oversee follow-up
	~~Multi-tasking (good time management)~~	Can manage more than one project at a time
	Smoothly transition roles as a leader and a team player	Shows ability to serve in multiple capacities
	~~Be trainable~~	Demonstrated completion of processes designed to improve managerial competence in non-academic credit awarding courses.
	~~Skill as a mentor: help others/foster development beyond training~~	Served as a training leader for one or more peers and/or subordinates

Level 1	Level 2	Definition of Level 2 Engineering Factor
Political	ID people & relationships in a variety of organizations as resources	Able to show the relationship of people in various roles both inside and outside of the work unit
	actions, Ability to convert organizational goals into source of influence: individual & teams	Can relate the overall mission into the operational procedures of the work unit
	Lack of political inclination (influence/respect vs. power) Recognize value of influence and power	Able to show that work is related to the outcome of the unit and not to the improvement of one's resume'
	Be adaptable	Demonstrates ability to serve in a variety of work roles and environments
	Able to maintain valuable alliances	Able to show resource cooperation over a six-month period of time
	Knowledge of which "fight to fight" and which one "not to fight": pick your battles	Can show ability to manage projects in budget reduction periods with regard to "Big Picture" compromise, and consequences.
V, 3	Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")	Served in a verity of projects internal and external to the work unit. variety

264

Level 1	Level 2	Definition of Level 2 Engineering Factor
Social	Good communication skills: able to switch gears and direct communication appropriately – change in audience	Able to speak to a variety of audiences *both orally and written.*
	Common sense	Primarily uses data as basis of decisions, but allows for group consensus, *also drawn from past experience*
	~~Good attitude~~	Positively contributes to promotion of the unit's culture
	Create a "win-win" atmosphere	Able to support multiple outcomes in a project *optimistic and positive attitude*
	Confidence and enthusiasm	Able to show proactive support for a group
	Relevant communication skills via computers [email]	Completed training or academic credit courses in business communications
	Form working relationships with a variety of people	Demonstrated membership in one or more groups within and without the work unit
	Aware and willing to "earn" respect in a manufacturing environment	Demonstrated peer experience in subordinate & superior relationships
	Communicate well both orally [info, persuasive] and written [info, persuasive]	Able to show group consensus achieved through oral, written and electronic communications media
	Sell ideas to others	Demonstrated competence in persuasive communications media
	Be a team player	Able to serve in a variety of roles in a work unit
	Get along in professional dynamics: how to get along in a group and with individual	Practical experience in team projects
	Skill as a mentor: help others, foster development beyond training	Demonstrated experience as a trainer of others, *including one-on-one. able to lead by example.*
	Listen and accept instructions	Demonstrated experience in understanding procedures and project requirements
	Able to give and take constructive criticism: professionalism, do not take things personally	Uses a variety of techniques to clarify and to reach consensus on requirements of tasks, *maintaining self-discipline.*

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Technical	Science & math background				
3✓	Application of the basics				
	Technical expert in particular field [skill]				
5✓	Able to define the problem – problem solving overall				
5✓	Able to analyze using specific tools – economic engineering, risk analysis				
6✓	Computer literate				
	Knowledge of industry standards				
6✓	Able to sell ideas to others				
3✓, 5✓	ISO 9002				
	Failure analysis techniques				
3✓, 6✓	Be trainable				
EXPERIENCE	Hands on experience = internships/co-ops				
3✓, 5✓	Hands on experience = machining, lathe, milling @ vo-tech				
	Did you have "real world" experience b/w degrees?				

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Managerial	Problem solving skills: breaking down into smaller elements				
	Able to analyze (i.e. engineering economics)				
	Plan a project, manage projects and budget estimates				
3✓	Understand team management in an overall environment				
	Understand the difference between repair and new manufacturing				
	Self-motivated				
3✓, 5✓	Seeks challenges/new ideas				
3✓	Be able to chair meetings [plan & direct]				
3✓	Multi-tasking [good time management]				
	Smoothly transition roles as a leader and a team player				
4✓	Be trainable				
5✓	Skill as a mentor: help others/foster development beyond training				
	able to sell ideas to others				

268

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Political	ID people & relationships in a variety of organizations as resources				
	Ability to convert organizational goals into source of influence: individual & teams				
	Lack of political inclination (influence/respect vs. power)				
	-Be adaptable-				
	Able to maintain valuable alliances				
2✓	-Knowledge of which "fight to fight" and which one "not to fight": pick your battles				
2✓	Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground")				
3✓ L2	Able to work within the confines set by governing rules and Regulations				

Level 1	Level 2	Level 3	Level 4	Delete	Reason(s) for change
Social	Good communication skills; able to switch gears and direct communication appropriately – change in audience				
	Common sense				
	Good attitude				
	Create a "win-win" atmosphere				
	Confidence and enthusiasm				
	Relevant communication skills via computers [email]				
	Form working relationships with a variety of people				
	Aware and willing to "earn" respect in a manufacturing environment				
	Communicate well both orally [info, persuasive] and written [info, persuasive]				
	Sell ideas to others				
	Be a team player				
	Get along in professional dynamics: how to get along in a group and with individual				
	Skill as a mentor: help others, foster development beyond training				
	Listen and accept instructions				
	Able to give and take constructive criticism: professionalism, do not take things personally				

Appendix 7 - Phase III Pretest – Version 2.0

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISON TOOL

		Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	
FACTOR A	FACTOR B										RATIONALE
PRIMARY FACTORS											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
SECONDARY FACTORS (INTERNAL BUSINESS PROCESSES)											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
SECONDARY FACTORS (LEARNING AND GROWTH)											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
SECONDARY FACTORS (CUSTOMERS)											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
SECONDARY FACTORS (FINANCE AND VALUE)											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
TECHNICAL											
Science & math background	Application of the basics	1	2	3	4	5	6	7	8	9	
Science & math background	Technical expert in particular field	1	2	3	4	5	6	7	8	9	
Science & math background	Able to define the poroblem - problem solving overall	1	2	3	4	5	6	7	8	9	
Science & math background	Able to analyze using specific tools - economic engineering, risk analysis	1	2	3	4	5	6	7	8	9	
Science & math background	computer literate	1	2	3	4	5	6	7	8	9	
Science & math background	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Science & math background	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Science & math background	ISO 9002	1	2	3	4	5	6	7	8	9	
Science & math background	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Science & math background	Be trainable	1	2	3	4	5	6	7	8	9	
Science & math background	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Science & math background	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Science & math background	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Application of the basics	Technical expert in particular field	1	2	3	4	5	6	7	8	9	
Application of the basics	Able to define the poroblem - problem solving overall	1	2	3	4	5	6	7	8	9	
Application of the basics	Able to analyze using specific tools - economic engineering, risk analysis	1	2	3	4	5	6	7	8	9	
Application of the basics	computer literate	1	2	3	4	5	6	7	8	9	
Application of the basics	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Application of the basics	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Application of the basics	ISO 9002	1	2	3	4	5	6	7	8	9	
Application of the basics	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Application of the basics	Be trainable	1	2	3	4	5	6	7	8	9	
Application of the basics	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Application of the basics	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Application of the basics	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Able to define the poroblem - problem solving overall	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Able to analyze using specific tools - economic engineering, risk analysis	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	computer literate	1	2	3	4	5	6	7	8	9	

Technical expert in particular field	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	ISO 9002	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Be trainable	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Able to analyze using specific tools - economic engineering, risk analysis	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	computer literate	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	ISO 9002	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Be trainable	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Able to define the poroblem - problem solving overall	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	computer literate	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	ISO 9002	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Be trainable	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Able to analyze using specific tools - economic engineering, risk analysis	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
computer literate	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
computer literate	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
computer literate	ISO 9002	1	2	3	4	5	6	7	8	9	
computer literate	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
computer literate	Be trainable	1	2	3	4	5	6	7	8	9	

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

computer literate	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
computer literate	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
computer literate	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Able to sell ideas to others	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	ISO 9002	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Be trainable	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	ISO 9002	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	Be trainable	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Able to sell ideas to others	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
ISO 9002	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
ISO 9002	Be trainable	1	2	3	4	5	6	7	8	9	
ISO 9002	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
ISO 9002	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
ISO 9002	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Be trainable	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Be trainable	Hands on experience -- internships/co-ops	1	2	3	4	5	6	7	8	9	
Be trainable	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Be trainable	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Hands on experience -- internships/co-ops	Hands on experience -- machining, lathe, milling @ vo-tech	1	2	3	4	5	6	7	8	9	
Hands on experience -- internships/co-ops	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Hands on experience -- machining, lathe, milling @ vo-tech	Did you have "real world" experience b/w degrees?	1	2	3	4	5	6	7	8	9	
Did you have "real world" experience b/w degrees?		1	2	3	4	5	6	7	8	9	

MANAGERIAL											
Problem solving skills: breaking down into smaller elements	Able to analyse (i.e. engineering economics)	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Understand lean management in an overall environment	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	self-motivated	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Be trainable	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Understand lean management in an overall environment	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	self-motivated	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Be trainable	1	2	3	4	5	6	7	8	9	
Able to analyse (i.e. engineering economics)	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Understand lean management in an overall environment	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	self-motivated	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Be trainable	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	

Understand lean management in an overall environment	self-motivated	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Be trainable	1	2	3	4	5	6	7	8	9	
Understand lean management in an overall environment	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	self-motivated	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Be trainable	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
self-motivated	Seeks challenges/new ideas	1	2	3	4	5	6	7	8	9	
self-motivated	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
self-motivated	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
self-motivated	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
self-motivated	Be trainable	1	2	3	4	5	6	7	8	9	
self-motivated	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Seeks challenges/new ideas	Be able to chair meetings [plan & direct]	1	2	3	4	5	6	7	8	9	
Seeks challenges/new ideas	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Seeks challenges/new ideas	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Seeks challenges/new ideas	Be trainable	1	2	3	4	5	6	7	8	9	
Seeks challenges/new ideas	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Be able to chair meetings [plan & direct]	Multi-tasking [good time management]	1	2	3	4	5	6	7	8	9	
Be able to chair meetings [plan & direct]	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Be able to chair meetings [plan & direct]	Be trainable	1	2	3	4	5	6	7	8	9	
Be able to chair meetings [plan & direct]	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Multi-tasking [good time management]	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Multi-tasking [good time management]	Be trainable	1	2	3	4	5	6	7	8	9	
Multi-tasking [good time management]	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	

Smoothly transition roles as a leader and a team player	Be trainable	1	2	3	4	5	6	7	8	9	
Smoothly transition roles as a leader and a team player	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Be trainable	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Skill as a mentor: help others/foster development beyond training		1	2	3	4	5	6	7	8	9	
POLITICAL											
ID people & relationships in a variety of organizations as resources	Ability to convert organizational goals into source of influence: individual &teams	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Lack of political inclination (influence/respcet vs. power)	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Be adaptable	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Knowledge of which "fight to fight" and which one "not to fight': pick your battles	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, finding a "common ground"	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual &teams	Lack of political inclination (influence/respcet vs. power)	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual &teams	Be adaptable	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual &teams	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual &teams	Knowledge of which "fight to fight" and which one "not to fight': pick your battles	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual &teams	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, finding a "common ground"	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respcet vs. power)	Be adaptable	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respcet vs. power)	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	

Lack of political inclination (influence/respcet vs. power)	Knowledge of which "fight to fight" and which one "not to fight': pick your battles	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respcet vs. power)	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, findiing a "common ground"	1	2	3	4	5	6	7	8	9	
Be adaptable	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Be adaptable	Knowledge of which "fight to fight" and which one "not to fight': pick your battles	1	2	3	4	5	6	7	8	9	
Be adaptable	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, findiing a "common ground"	1	2	3	4	5	6	7	8	9	
Able to maintain valuable alliances	Knowledge of which "fight to fight" and which one "not to fight': pick your battles	1	2	3	4	5	6	7	8	9	
Able to maintain valuable alliances	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, findiing a "common ground"	1	2	3	4	5	6	7	8	9	
Knowledge of which "fight to fight" and which one "not to fight': pick your battles	ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, findiing a "common ground"	1	2	3	4	5	6	7	8	9	
ability to work different political circles/ levels - be able to compromise with others (I.e. make use of limited resources, findiing a "common ground"		1	2	3	4	5	6	7	8	9	
SOCIAL											
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Common sense	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Good attitude	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Relevant communication skills via computers [email]	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	

Good communication skills: able to switch gears and direct communication appropriately - change in audience	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	sell ideas to others	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Be a team player	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Common sense	Good attitude	1	2	3	4	5	6	7	8	9	
Common sense	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Common sense	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Common sense	Relevant communication skills via computers [email]	1	2	3	4	5	6	7	8	9	
Common sense	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	
Common sense	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Common sense	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Common sense	sell ideas to others	1	2	3	4	5	6	7	8	9	

Common sense	Be a team player	1	2	3	4	5	6	7	8	9	
Common sense	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Common sense	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Common sense	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Common sense	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Good attitude	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Good attitude	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Good attitude	Relevant communication skills via computers [email]	1	2	3	4	5	6	7	8	9	
Good attitude	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	
Good attitude	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Good attitude	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Good attitude	sell ideas to others	1	2	3	4	5	6	7	8	9	
Good attitude	Be a team player	1	2	3	4	5	6	7	8	9	
Good attitude	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Good attitude	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Good attitude	Listen and accept instructions	1	2	3	4	5	6	7	8	9	

Good attitude	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Relevant communication skills via computers [email]	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	sell ideas to others	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Be a team player	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Relevant communication skills via computers [email]	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	

Confidence and enthusiasm	sell ideas to others	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Be a team player	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Form working relationships with a variety of people	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	sell ideas to others	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Be a team player	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Relevant communication skills via computers [email]	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Aware and willing to "earn"respect in a manufacturing environment	1	2	3	4	5	6	7	8	9	

Form working relationships with a variety of people	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	sell ideas to others	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Be a team player	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Form working relationships with a variety of people	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Communicate well both orally [info, persuasive] and written [info, persuasive]	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	sell ideas to others	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Be a team player	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Aware and willing to "earn"respect in a manufacturing environment	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Communicate well both orally [info, persuasive] and written [info, persuasive]	sell ideas to others	1	2	3	4	5	6	7	8	9	
Communicate well both orally [info, persuasive] and written [info, persuasive]	Be a team player	1	2	3	4	5	6	7	8	9	

Communicate well both orally [info, persuasive] and written [info, persuasive]	Get along in a professional dynamics: how to get along ina group and with individual	1	2		4	5	6	7	8	9	
Communicate well both orally [info, persuasive] and written [info, persuasive]	Skill as a mentor: help others/foster development beyond training	1	2		4	5	6	7	8	9	
Communicate well both orally [info, persuasive] and written [info, persuasive]	Listen and accept instructions	1	2		4	5	6	7	8	9	
Communicate well both orally [info, persuasive] and written [info, persuasive]	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
sell ideas to others	Be a team player	1	2	3	4	5	6	7	8	9	
sell ideas to others	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
sell ideas to others	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
sell ideas to others	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
sell ideas to others	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Be a team player	Get along in a professional dynamics: how to get along ina group and with individual	1	2	3	4	5	6	7	8	9	
Be a team player	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Be a team player	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Be a team player	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Get along in a professional dynamics: how to get along ina group and with individual	Skill as a mentor: help others/foster development beyond training	1	2	3	4	5	6	7	8	9	
Get along in a professional dynamics: how to get along ina group and with individual	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Get along in a professional dynamics: how to get along ina group and with individual	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	

Skill as a mentor: help others/foster development beyond training	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Skill as a mentor: help others/foster development beyond training	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Listen and accept instructions	Able to give and take constructive criticism; professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Able to give and take constructive criticism; professionalism, do not take things personally		1	2	3	4	5	6	7	8	9	
SECONDARY FACTORS (FINANCE AND VALUE)											
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	
		1	2	3	4	5	6	7	8	9	

Appendix 8 - Final Survey Pretest

MEMORANDUM

DATE: 4 April 2003

TO: Dr. Tim Bridges
Dr. Saba Bahouth
Dr. Jerry Allison

FROM: Mr. Dave Hartmann

SUBJECT: Request for a Dissertation Pilot Study

Gentlemen,

My Oklahoma State University Ph.D. committee seeks documented input on the survey to be used in the final phase of the research effort. Would you please review the research instrument and provide me written comments on the "Dissertation Pilot Evaluation Form"?

I request completion by Wednesday, April 9th to meet project deadlines. Please contact me to answer any questions, x-2839.

Thank you very much.

Attachments: (2)

1. *Dissertation Pilot Evaluation Form*
2. *The Research instrument*

Dissertation Pilot Evaluation

***** Instructions *****

Upon completion of the survey, please respond to the following questions in the space provided. Check the box that most accurately discribes your reaction to each of the questions. In the space for "remarks", you may describe the reason(s) for your selections. Please continue your remarks on the back of the form or upon additional sheets, as needed. Thank you.

	Measure of Agreement				
Pilot Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
(1) The paired judgement forms were easy to use					
Remarks:					
(2) The instructions were easy to understand.					
Remarks:					
(3) The instructions were helpful.					
Remarks:					

A Process To Model Customer-Focused Engineering Program Alignment By Means Of Group Consensus And Analytical Hierarchical Process Analysis:

The Research Instrument

Prepared by:

David H. Hartmann

Oklahoma State University

29 March 2003

***** INSTRUCTIONS *****

ANALYTICAL HIERARCHY PROCESS
PAIRED COMPARISON INSTRUMENT

For each paired comparison, please circle the Factor (Factor A or Factor B) that is more important in the selection of the ideal graduate engineering candidate. A definition of each Primary (Level 1) and Secondary (Level 2) Factor is provided. If both factors are equally important, then circle both. Evaluate the most important factor by circling the degree of importance or preference using the nine-point scale below:

If the factor is:	the rating to assign is
Equally important or preferred	**1**
Weakly important or preferred	**3**
Strongly important or preferred	**5**
Very strongly important or preferred	**7**
Absolutely important or preferred	**9**

Please note that even numbers (2, 4, 6, 8) may be considered compromises between the preference ratings.

You may document your rationale for your preferences in the space provided.

***** Example *****

		Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	
FACTOR - A	FACTOR - B										RATIONALE
PRIMARY FACTORS											
Technical	Managerial	1	2	3	4	5	6	7	8	9	
Technical	Political	1	2	3	4	5	6	7	8	9	
Technical	Social	1	2	3	4	5	6	7	8	9	
Managerial	Political	1	2	3	4	5	6	7	8	9	
Managerial	Social	1	2	3	4	5	6	7	8	9	
Political	Social	1	2	3	4	5	6	7	8	9	

Primary Factor Definitions

Technical
Specialized knowledge and expertise used to carry out particular techniques or procedures.

Managerial
Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Political
Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.

Social
The ability to work with, understand, communicate with and motivate other people, both individually and in groups.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

		Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	
FACTOR - A	FACTOR - B										RATIONALE
PRIMARY FACTORS											
Technical	Managerial	1	2	3	4	5	6	7	8	9	
Technical	Political	1	2	3	4	5	6	7	8	9	
Technical	Social	1	2	3	4	5	6	7	8	9	
Managerial	Political	1	2	3	4	5	6	7	8	9	
Managerial	Social	1	2	3	4	5	6	7	8	9	
Political	Social	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Technical	Science & math background	Received college-level academic credit for science and mathematics. Able to apply the basics: demonstrates practical evidence of using science, math, and engineering in practice. Able to analyze using specific tools – economic engineering, risk analysis: Able to use engineering formulae and processes basic to project management.
	Technical expert in particular field [skill]	Academic credit received for more than one course in subject area at the graduate level. Able to define the problem – problem solving overall: Able to show evidence of using a scientific method.
	Knowledge of industry standards	Is familiar with standards and codes used in the industry, not including international standards such as ISO.
	Failure analysis techniques	Familiar with Failure Mode and Effects Analysis (FMEA).
	Experience	Completed an internship or co-op experience. Demonstrated practical experience in basic skills such as machining, lathe operation, milling, and so forth. Following undergraduate degree, does the candidate have practical work experience?

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (TECHNICAL)											
Science & math background	Technical expert in particular field	1	2	3	4	5	6	7	8	9	
Science & math background	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Science & math background	Failure analysis techniques	1	2	3	4	5	8	7	8	9	
Science & math background	Experience	1	2	3	4	6	6	7	8	9	
Technical expert in particular field	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Failure analysis techniques	1	2	3	4	6	6	7	8	9	
Technical expert in particular field	Experience	1	2	3	4	5	8	7	8	9	
Knowledge of industry standards	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Experience	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Experience	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Managerial	Problem solving skills: breaking down into smaller elements	Evidence of using scientific method
	Able to analyze (i.e. engineering economics)	Able to use methodological basic engineering formulae
	Plan a project, manage projects and budget estimates	Knowledgeable and demonstrate practical experience in project management skills. Be able to chair meetings [plan & direct] Multi-tasking [good time management]
	Understand the difference between repair and new manufacturing	Understands asset-driven and raw material manufacturing. Understands lean management in an overall environment
	Self-motivated	Works without supervisory oversight in most endeavors
	Smoothly transition roles as a leader and a team player	Shows ability to serve in multiple capacities

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (MANAGERIAL)											
Problem solving skills: breaking down into smaller elements	Able to analyze (i.e., engineering economics)	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Self-motivated	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Self-motivated	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Self-motivated	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Self-motivated	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Self-motivated	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Political	ID people & relationships in a variety of organizations as resources	Able to show the relationship of people in various roles both inside and outside of the work unit. Knowledge of which "fight to fight" and which one "not to fight": pick your battles: Can show ability to manage projects with regard to "big picture" – compromise, risk, and consequences. Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground"): Served in a variety of projects internal and external to the work unit.
	Ability to convert organizational goals into source of influence: individual & teams	Can relate the overall mission into the operational procedures of the work unit.
	Lack of political inclination (influence/respect vs. power)	Able to show that work is related to the outcome of the unit and not to the improvement of one's resume'.
	Able to maintain valuable alliances	Able to show resource cooperation over a six-month period of time.
	Able to work within a structure set by organizational rules and regulations.	Able to positively impact organizational performance.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (POLITICAL)											
ID people & relationships in a variety of organizations as resources	Ability to convert organizational goals into source of influence: individual & teams	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Lack of political inclination (influence/respect vs. power)	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Lack of political inclination (influence/respect vs. power)	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respect vs. power)	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respect vs. power)	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Able to maintain valuable alliances	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Social	Good communication skills: able to switch gears and direct communication appropriately to a change in audience	Able to speak and write to a variety of audiences. Able to sell ideas to others: Demonstrated experience as product or process champion. Completed training or academic credit courses in business communications.
	Common sense	Primarily uses data as basis of decisions, but allows for group consensus.
	Create a "win-win" atmosphere	Able to support multiple outcomes in a project. Aware and willing to "earn" respect in a manufacturing environment: Demonstrated peer experience in subordinate & superior relationships
	Confidence and enthusiasm	Able to show proactive support for a group.
	Get along in professional dynamics: how to get along in a group and with individual	Practical experience in team projects. Form working relationships with a variety of people: Demonstrated membership in one or more groups within and without the work unit. Be a team player: Able to serve in a variety of roles in a work unit. Skill as a mentor: help others, foster development beyond training: Demonstrated experience as a trainer of others.
	Listen and accept instructions	Demonstrated experience in understanding procedures and project requirements.
	Able to give and take constructive criticism: professionalism, do not take things personally	Uses a variety of techniques to clarify and to reach consensus on requirements of tasks.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (SOCIAL)											
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Common sense	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Common sense	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Common sense	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Common sense	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Common sense	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Common sense	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Get along in professional dynamics: how to get along in a group and with individual	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Get along in professional dynamics: how to get along in a group and with individual	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Listen and accept instructions	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	

Appendix 9 - Final Survey Package: Oklahoma City Air Logistics Center

David H. Hartmann
2801 Sweetbriar
Edmond, Oklahoma 73034-6554
Dhartm0669@aol.com

April 9, 2003

Dr. Wayne Jones
OC-ALC/ENF
3001 Staff Drive, Suite T-67
Tinker Air Force Base, Oklahoma 73145-3038

Dear Dr. Jones:

Thank you very much for your participation in the OC-ALC & OSU study of Oklahoma manufacturers. This letter is a status report and introduction of Phase 3, the final phase of the research project.

Phase 1. Completed late December 2002.

Phase 2. Completed 17 March 2003.

Phase 3. I developed a research survey based on condensing the collective feedback from the OC-ALC team submitted in Phase 2. In this Phase 3 survey, I ask that you judge between desirable characteristics of graduate engineers seeking employment in your unit, selecting one characteristic over the other or voting them equal in importance. I included an instruction sheet to the survey, which follows the title page [attached].

Dr. Jones, please complete and return the survey package by 18 April 2003. A self-addressed stamped envelope is included for your convenience.

Your continued voluntary participation is essential to the success of the research.

Should you have any questions regarding Phase 3 or any other questions concerning the project please contact me at 405-974-2839 or via email at dhartmann@ucok.edu. I would be very pleased to help you in any way.

I am very grateful for your interest, assistance, and cooperation.

Respectfully,

David H. Hartmann
Principal Investigator

Encl.: (1) *"The Research Instrument"*

CC: Each team member,
Kenneth Case, Ph.D.

A Process To Model Customer-Focused Engineering Program Alignment By Means Of Group Consensus And Analytical Hierarchical Process Analysis:

The Research Instrument

Prepared by:

David H. Hartmann

Oklahoma State University

29 March 2003

***** INSTRUCTIONS *****

ANALYTICAL HIERARCHY PROCESS
PAIRED COMPARISON INSTRUMENT

For each paired comparison, please circle the Factor (Factor A or Factor B) that is more important in the selection of the ideal graduate engineering candidate. A definition of each Primary (Level 1) and Secondary (Level 2) Factor is provided. If both factors are equally important, then circle both. Evaluate the most important factor by circling the degree of importance or preference using the nine-point scale below:

If the factor is:	the rating to assign is
Equally important or preferred	**1**
Weakly important or preferred	**3**
Strongly important or preferred	**5**
Very strongly important or preferred	**7**
Absolutely important or preferred	**9**

Please note that even numbers (2, 4, 6, 8) may be considered compromises between the preference ratings.

You may document your rationale for your preferences in the space provided.

***** Example *****

		Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	
FACTOR - A	FACTOR - B										RATIONALE
PRIMARY FACTORS											
Technical	Managerial	1	2	3	4	5	6	7	8	9	
Technical	Political	1	2	3	4	5	6	7	8	9	
Technical	Social	1	2	3	4	5	6	7	8	9	
Managerial	Political	1	2	3	4	5	6	7	8	9	
Managerial	Social	1	2	3	4	5	6	7	8	9	
Political	Social	1	2	3	4	5	6	7	8	9	

Primary Factor Definitions

Technical
Specialized knowledge and expertise used to carry out particular techniques or procedures.

Managerial
Ability to get things done by planning, organizing, directing, and controlling others in the organization.

Political
Ability to enhance his or her power, build a power base, and establish "right" connections in the organization.

Social
The ability to work with, understand, communicate with and motivate other people, both individually and in groups.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

		Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	
FACTOR - A	FACTOR - B										RATIONALE
PRIMARY FACTORS											
Technical	Managerial	1	2	3	4	5	6	7	8	9	
Technical	Political	1	2	3	4	5	6	7	8	9	
Technical	Social	1	2	3	4	5	6	7	8	9	
Managerial	Political	1	2	3	4	5	6	7	8	9	
Managerial	Social	1	2	3	4	5	6	7	8	9	
Political	Social	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Technical	Science & math background	Received college-level academic credit for science and mathematics. Able to apply the basics: demonstrates practical evidence of using science, math, and engineering in practice. Able to analyze using specific tools -- economic engineering, risk analysis: Able to use engineering formulae and processes basic to project management.
	Technical expert in particular field [skill]	Academic credit received for more than one course in subject area at the graduate level. Able to define the problem -- problem solving overall: Able to show evidence of using a scientific method.
	Knowledge of industry standards	Is familiar with standards and codes used in the industry, not including international standards such as ISO.
	Failure analysis techniques	Familiar with Failure Mode and Effects Analysis (FMEA).
	Experience	Completed an internship or co-op experience. Demonstrated practical experience in basic skills such as machining, lathe operation, milling, and so forth. Following undergraduate degree, does the candidate have practical work experience?

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (TECHNICAL)											
Science & math background	Technical expert in particular field	1	2	3	4	5	6	7	8	9	
Science & math background	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Science & math background	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Science & math background	Experience	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Knowledge of industry standards	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Technical expert in particular field	Experience	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Failure analysis techniques	1	2	3	4	5	6	7	8	9	
Knowledge of industry standards	Experience	1	2	3	4	5	6	7	8	9	
Failure analysis techniques	Experience	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Managerial	Problem solving skills: breaking down into smaller elements	Evidence of using scientific method
	Able to analyze (i.e. engineering economics)	Able to use methodological basic engineering formulae
	Plan a project, manage projects and budget estimates	Knowledgeable and demonstrate practical experience in project management skills. Be able to chair meetings [plan & direct] Multi-tasking [good time management]
	Understand the difference between repair and new manufacturing	Understands asset-driven and raw material manufacturing. Understands lean management in an overall environment
	Self-motivated	Works without supervisory oversight in most endeavors
	Smoothly transition roles as a leader and a team player	Shows ability to serve in multiple capacities

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (MANAGERIAL)											
Problem solving skills: breaking down into smaller elements	Able to analyze (i.e., engineering economics)	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Self-motivated	1	2	3	4	5	6	7	8	9	
Problem solving skills: breaking down into smaller elements	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Plan a project, manage projects and budget estimates	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Self-motivated	1	2	3	4	5	6	7	8	9	
Able to analyze (i.e., engineering economics)	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Understand the difference between repair and new manufacturing	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Self-motivated	1	2	3	4	5	6	7	8	9	
Plan a project, manage projects and budget estimates	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Self-motivated	1	2	3	4	5	6	7	8	9	
Understand the difference between repair and new manufacturing	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	
Self-motivated	Smoothly transition roles as a leader and a team player	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Political	ID people & relationships in a variety of organizations as resources	Able to show the relationship of people in various roles both inside and outside of the work unit. Knowledge of which "fight to fight" and which one "not to fight": pick your battles: Can show ability to manage projects with regard to "big picture" – compromise, risk, and consequences. Ability to work different political circles/levels – be able to compromise with others (i.e. make use of limited resources, finding a "common ground"): Served in a variety of projects internal and external to the work unit.
	Ability to convert organizational goals into source of influence: individual & teams	Can relate the overall mission into the operational procedures of the work unit.
	Lack of political inclination (influence/respect vs. power)	Able to show that work is related to the outcome of the unit and not to the improvement of one's resume'.
	Able to maintain valuable alliances	Able to show resource cooperation over a six-month period of time.
	Able to work within a structure set by organizational rules and regulations.	Able to positively impact organizational performance.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (POLITICAL)											
ID people & relationships in a variety of organizations as resources	Ability to convert organizational goals into source of influence: individual & teams	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Lack of political inclination (influence/respect vs. power)	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
ID people & relationships in a variety of organizations as resources	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Lack of political inclination (influence/respect vs. power)	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Ability to convert organizational goals into source of influence: individual & teams	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respect vs. power)	Able to maintain valuable alliances	1	2	3	4	5	6	7	8	9	
Lack of political inclination (influence/respect vs. power)	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	
Able to maintain valuable alliances	Able to work within a structure set by Government Rules/Regulations	1	2	3	4	5	6	7	8	9	

Level 1	Level 2	Definition of Level 2 Engineering Factor
Social	Good communication skills: able to switch gears and direct communication appropriately to a change in audience	Able to speak and write to a variety of audiences. Able to sell ideas to others: Demonstrated experience as product or process champion. Completed training or academic credit courses in business communications.
	Common sense	Primarily uses data as basis of decisions, but allows for group consensus.
	Create a "win-win" atmosphere	Able to support multiple outcomes in a project. Aware and willing to "earn" respect in a manufacturing environment: Demonstrated peer experience in subordinate & superior relationships
	Confidence and enthusiasm	Able to show proactive support for a group.
	Get along in professional dynamics: how to get along in a group and with individual	Practical experience in team projects. Form working relationships with a variety of people: Demonstrated membership in one or more groups within and without the work unit. Be a team player: Able to serve in a variety of roles in a work unit. Skill as a mentor: help others, foster development beyond training: Demonstrated experience as a trainer of others.
	Listen and accept instructions	Demonstrated experience in understanding procedures and project requirements.
	Able to give and take constructive criticism: professionalism, do not take things personally	Uses a variety of techniques to clarify and to reach consensus on requirements of tasks.

ANALYTIC HIERARCHY PROCESS
PAIRWISE COMPARISION TOOL

FACTOR A	FACTOR B	Equally Important		Weakly More Important		Strongly More Important		Very Strongly More Important		Absolutely More Important	RATIONALE
SECONDARY FACTORS (SOCIAL)											
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Common sense	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Good communication skills: able to switch gears and direct communication appropriately - change in audience	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Common sense	Create a "win-win" atmosphere	1	2	3	4	5	6	7	8	9	
Common sense	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Common sense	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Common sense	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Common sense	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Confidence and enthusiasm	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Create a "win-win" atmosphere	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Get along in professional dynamics: how to get along in a group and with individual	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Confidence and enthusiasm	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Get along in professional dynamics: how to get along in a group and with individual	Listen and accept instructions	1	2	3	4	5	6	7	8	9	
Get along in professional dynamics: how to get along in a group and with individual	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	
Listen and accept instructions	Able to give and take constructive criticism: Professionalism, do not take things personally	1	2	3	4	5	6	7	8	9	

Appendix 10 - Final Survey Package: Boeing Integrated Defense Systems

David H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

March 29, 2003

Dear Mr. Crutchfield:

Thank you for the opportunity to brief you on the research I am conducting for the Ph. D., Industrial Engineering and Management, Oklahoma State University. To that end, my research advisor and I appreciate the meeting set for Thursday, April 3, 2003.

As requested, I have enclosed a copy of the research instrument (Tab 4) and several additional documents I thought would help explain the research. Included is a description of the project (Tab 1), a suggested approval letter to me from the Company permitting me to survey its employees (Tab 2), and my *Curriculum Vitae* (Tab 5).

I am at a critical (and time sensitive - sooner is much better) juncture in the dissertation effort and I need the support of engineering managers to complete a research instrument and to return it in a self-addressed stamped envelope. Subsequent communications would only be required to clarify their responses where the analysis reveals some statistical inconsistency. Bottom line - the right people who would have about two hours each invested. I have included a permission form I request the participants individually approve and return to me with the completed instrument (Tab 3).

What's in it for Boeing-Saint Louis? Potentially, it would lead to the ability to articulate engineering needs for future hires. It would also likely help Boeing assess educational programs for new and current hires. I am assured that from OSU's point of view, it would greatly help them (through my research) to understand the characteristics of graduate engineers from the point of view of the consumer (e.g., Boeing and its supporting suppliers), to then be aligned with thoughts, practices, and biases from the academic side. Of course, Boeing would receive any articles that distill the research effort into useful conclusions.

John, I'll telephone your secretary Wednesday morning to confirm. I have an airline reservation for a mid-afternoon arrival on the 2nd and a mid-afternoon departure on the 3rd. I have made arrangements for lodging and transportation. Neenah has provided driving/arrival instructions, which I will reconfirm.

Thanks again. I'm looking forward to meeting you and your Boeing team!

Respectfully,

David H. Hartmann

Attachments (5)

Home: 405.359.3995 Dhartm0669@aol.com
Office: 405.974.2839 dhartmann@ucok.edu

Date:	**March 29, 2003**
Research Project:	**"A Process To Model Customer-Focused Engineering Program Alignment By Means Of Group Consensus And Analytical Hierarchical Process Analysis"**
Principal Investigator(s):	**Kenneth E. Case, Ph.D., Regents Professor, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma**
	David H. Hartmann, Instructor, University of Central Oklahoma and Ph.D. Student, Industrial Engineering and Management, Oklahoma State University

EXECUTIVE SUMMARY

Engineering graduate program outcomes and employer requirements must be effectively and efficiently aligned to provide graduates who are academically prepared to support the challenges and opportunities of contemporary manufacturing enterprises. Current assessment methods do not provide a demand-based approach to drive the eventual adoption and emphasis of engineering program topics and courses to achieve this alignment. The research project will develop a process that will align both manufacturing companies and colleges and universities in their expectations and programming for engineering graduates.

The Research Objective

The objective of this research project is to determine a methodology or sequential approach to operationalize the collective expectations of manufacturing stakeholders so as to align a graduate engineering program for industrial and engineering management programs by measuring the judgments of a specific research frame of engineering consumers - manufacturing companies. In sum, we need to know "what it takes to achieve alignment." The research project will deliver a methodological process for alignment of engineering program outcomes and company needs validated by reference to an expert panel of faculty and industry representatives. The study has been designed using the methods for conducting descriptive survey research, because it is important to develop an understanding about the current status of the phenomena of goals alignment and then, to ultimately generalize to a broader set of engineering graduate consumers. By a "broader set of engineering graduates", it is assumed that the research could be expanded at a later date to include other research frames [other NAICS consumers, regions, and non-NAICS end users, such as government and higher education] and terminal degree levels [such as the associates and baccalaureate degrees].

Sub-objectives

In order to meet this objective of this research project, the following questions and objectives need to be answered:

Sub-objective 1.

What are the priorities of NAICS coded 31-33 manufacturing companies for the outcomes of a graduate engineering program?

Sub-objective 2.

Develop a general classification of graduate manufacturing engineering program outcomes.

Sub-objective 3.

What are the characteristics of engineering program alignment with the expectations of the ultimate consumer?

Sub-objective 4.

Are there differences between the graduate manufacturing engineering program outcomes and the priorities of NAICS coded 31-33 manufacturing companies. If there are differences, are they significant?

Methods to Answer the Sub-Objectives of the Research

Sub-objective 1. What are the priorities of NAICS coded 31-33 manufacturing companies for the outcomes of a graduate engineering program?

The following methodological steps will use primary and secondary data.

(1) Identify and meet with OAME member companies in order to,
(2) Conduct NGT and Affinity Diagram sessions with OAME manufacturing companies for weighted judgments, and to
(3) Analyze the groups' comparative judgments using analytical hierarchical processes and Expert Choice software (Expert Choice, 2002).

Sub-objective 2. Develop a general classification of graduate manufacturing engineering program outcomes.

The following methodological steps will use primary and secondary data.

(1) Review extant literature on curricula designs.
(2) Conduct structured interview of expert panel - academics.
(3) Develop a general model of graduate engineering programs and distribute to experts in a three step "Delphi method".
    a. Distribute and collect returned surveys of engineering program outcomes.
    b. Develop a first collective list of outcomes.
    c. Re-distribute list and collect second review using the affinities of technical, managerial, social, and political groups.
    d. Distribute final list for weighted judgments.
(4) Analyze comparative judgments using analytical hierarchical processes and Expert Choice software (Expert Choice, 2002).

Sub-objective 3. What are the characteristics of engineering program alignment?

(1) Conduct structured interview of expert panel – academics.
(2) Conduct structured interview of expert panel - manufacturing.
(3) Review extant literature on BNQA Education sector winners.
(4) Develop a collective list of characteristics.
(5) Develop a general model of graduate engineering programs and distribute to experts in a three step "Delphi method".
    a. Distribute and collect returned surveys of engineering program outcomes.
    b. Develop a first collective list of outcomes.
    c. Re-distribute list and collect second review.
    d. Distribute final list for weighted judgments.
(5) Analyze comparative judgments using analytical hierarchical processes.

Sub-objective 4. Are there differences between the graduate manufacturing engineering program outcomes and the priorities of NAICS coded 31-33 manufacturing companies. If there are differences, are they significant?

(1) Use ANOVA for checking the differences between the consistencies of the weighted judgments.

FACT SHEET

Who?

	Researcher	Advisor
Name	David H. Hartmann	Kenneth E. Case, Ph.D.
Title	Ph.D. student, Oklahoma State University, Instructor, University of Central Oklahoma	Regents Professor, School of Industrial Engineering & Management, Oklahoma State University
Address	2801 Sweetbriar Edmond OK 73034-6554	322 Engineering North Stillwater OK 74078
Phone	405.974.2839 [office] 405.359.3995 [home] 405.812.3995 [cell]	405.744-6055 [office]
E-Mail	dhartmann@ucok.edu	kcase@okstate.edu

What? This is a research study of manufacturing companies, which seeks to determine a process to align manufacturing company-engineering needs with higher education's programs in Oklahoma and neighboring states.

When? Present to July, 2003

Where? Questionnaire completion

Why?

Primary Purpose
To develop a consensus position for manufacturing companies regarding master's degree level engineering candidate education.

Secondary Purpose
To deliver the research study.

Tertiary Purpose
To obtain research data for Mr. Hartmann's Ph.D. dissertation,

How? By facilitating a two-hour meeting with participating companies using the widely proven group consensus process known as the "Nominal Group Technique".

Resources required?

Approximately seven to ten companies are needed for the meeting. From the companies, a single point-of-contact should be identified. This individual should be assigned in a "management" activity; have five or more years of engineering experience; and provided some input to one or more budget cycles.

FREQUENTLY ASKED QUESTIONS

What is the purpose of the research?
The research has three purposes:

Primary Purpose
To develop a consensus position for manufacturing companies regarding master's degree level engineering candidate education.

Secondary Purpose
To deliver the research study.

Tertiary Purpose
To obtain research data for Mr. Hartmann's Ph.D. dissertation,

Who are the subjects in the study?
There are two research groups in the study. The first is a group of manufacturing company representatives, who have operations, budget, and engineering experience. The second group is comprised of manufacturing engineering faculty representatives from Oklahoma, Missouri, and Arkansas.

Will the participants encounter the possibility of stress or physical, psychological, or legal risks?
No. There are absolutely no questions asked of a personal nature beyond one's name and business address. No responses will be coded back to any individual, since a third party clerk will receive and "bank" all responses. No intentionally sensitive questions will be asked.

Will the subjects be deceived or misled in any way?
There will not be any intentional deception. The name and contact information of the researcher will be available for contact at any time throughout the study.

Will the subjects be presented with materials that might be considered offensive, threatening, or degrading?
No such materials will be offered the subjects.

Will any inducements be offered the subjects for their participation?
No.

Will a written consent form be used?
Yes. The subjects will be volunteers; the study will be explained to the sponsoring agency, OAME, and in the letter of invitation; and the purpose, confidentiality of the study will be briefly explained to the subjects once again prior to the study initiation.

DAVID H. HARTMANN

Office Address

Instructor,
Department of Information Systems and Operations Management,
College of Business Administration,
University of Central Oklahoma
100 North University drive
Edmond, OK 73034

(405) 974-2839
Fax (405) 974-3821
E-mail: dhartmann@ucok.edu

Home Address

2801 Sweetbriar
Edmond, OK 73034-6554

(405) 359-3995
E-mail: DHartm0669@aol.com

SUMMARY OF EXPERIENCE IN EDUCATIONAL SETTING

- Designed and built the ***Division of Business and Decision Sciences*** at a private university in central Oklahoma.
- Taught and advised in lower and upper-division, university-level courses in traditional classroom, on-line, independent, INTERNET-based, and directed-study modalities for a diversity of traditional and non-traditional undergraduate students.
- Developed, taught and managed Adult Basic Education and training programs for ethnically diverse and under-educated employees in a corporate manufacturing setting.
- Developed and monitored technical training programs for international adult students.
- Initiated and coordinated educational partnerships between businesses, labor unions, and state-level and public secondary school districts.
- Initiated, directed, taught, and supplied leadership and industrial safety training programs for salaried corporate manufacturing managers, supervisors, and hourly wage employees in a manufacturing setting.

EDUCATION

ABD (Ph.D., Candidate) Industrial Engineering and Management Oklahoma State University, Stillwater, OK	1998
Master of Business Administration, College of William and Mary, Williamsburg, VA	1987
Master of Science, Logistics Management Air Force Institute of Technology, Dayton, OH	1976
Bachelor of Science, Political Science and History United States Air Force Academy, Colorado Springs, CO	1969

EMPLOYMENT HISTORY

University of Central Oklahoma, Edmond, OK 2000-Present
Instructor, Department of Information Systems and Operations Management

- Teaching Experience:
  - Production and Operations Management (Undergraduate),
  - Methods of Operations Supervision (Undergraduate),
  - Management Science (Undergraduate and Graduate), and
  - Management Information Systems (Undergraduate).
- Serves on a variety of Departmental academic committees:
  - Department Liaison to the Max Chambers Library, 2001-Present
  - Honors and Scholarship Committee, 2000-2001
  - Department Program Review Committee, 2000-2001
  - Liaison to Rose State College – Operations Management, 2001-Present
- Served on the University's Presidential Leadership Council Scholarship Screening Committee, 2000-2001

Saint Gregory's University, Shawnee, OK 1996-2000
Chair, Division of Business and Decision Sciences

- Set Division policy, developed the business core academic curriculum, and developed, tracked, and reported variances in annual division budgets.
- Sourced, screened, interviewed, and recommended full-time and adjunct faculty.
- Instructed fifteen (15) equated credit hours of quantitative and qualitative upper division courses per academic semester.
- Recruited, enrolled, and advised students.
- Developed a unique, integrative fourteen credit hour program in **Professional Development** required of all university students.
- Teaching Experience: (all undergraduate)
  - Production and Operations Management,
  - Principles of Management,
  - Total Quality Management,
  - Organizational Policies and Practices (Interdisciplinary general education course),
  - Principles of Business Communication,
  - International Management, and
  - Senior Seminar: Business Research and Strategy.
- Co-Chair, University Academic Council.
- Served on a variety of academic committees:
  - Co-chair of the Technology Integration Project Team, which developed and implemented the campus-wide adoption of laptop computers by students, faculty, and staff.

- Served on the Distance Learning Implementation Team,
- Served on the Library Resources Committee,
- Served on the University Self-Assessment Committee, and
- Served on the University Adults Completing Education (A.C.E.) Committee.

Oklahoma State University, Stillwater, OK 1994-Present
Doctoral Candidate and Graduate Research Assistant

- Completed all course work towards the Ph.D. in Industrial Engineering and Management. GPA: 3.35/4.00. Elected to *Alpha Pi Mu* -- National Industrial Engineering Honor Society. Graduate Teaching Assistant, 1994-96.
- Served as research assistant in an OSU and federal government cooperative Computer Assisted Technology Transfer Program (CATT) grant whose goal is the transfer of manufacturing technologies and training to Oklahoma manufacturers.

Gaylord Container Corporation, Rochester, NY 1990-94
Quality Process Manager

- Chaired the manufacturing plant quality council and facilitated 25 quality improvement teams.
- Implemented procedures and monitored statistical data to assure assessment standards were achieved in areas of personnel training, product manufacturing, and supplier selection.
- Initiated and developed procedures for supplier certification in accordance with ISO-9000 standards series. Documented success led to corporate-wide adoption in selected manufacturing operations and supplier certification.
- Initiated and hired engineering student interns for plant-wide quality improvement.
- Served on the facility's various social and community service committees.

United States Air Force 1969-90
Retired Rank: Lieutenant Colonel

SUMMARY OF EXPERIENCE IN MILITARY SETTING

During term of commissioned service, rapidly progressed through positions of increasing leadership and management responsibility including instructor pilot, standards and evaluation pilot, operations officer, squadron commander, and program and project manager.

Summary of career experience includes:

10 years Designed and managed programs for evaluating and financially controlling flying training and technical education courses in the United States Air Force and in twenty-two (22) foreign air forces.

10 years	Developed and managed annual operating budgets in excess of $500,000.
6 years	Managed forty-five (45) flight training program evaluations and needs. assessments.
5 years	Designed and implemented assessment programs for ten (10) aviation-training organizations.
5 years	Initiated and implemented improved logistics assessment designs for organizations in the United States Air Force and three (3) foreign air forces on behalf of the United States, Department of State.

Military career highlights

- Instructor pilot and flight examiner: E-3A, B, C AWACS and EC/KC-135A aircraft.
- Veteran: Vietnam War and Persian Gulf Conflict and numerous contingency air campaigns of national significance.
- Accredited: *Professional Designation in Logistics Management.*
- Recognized nationally for most outstanding graduate thesis in logistics management (1976). Thesis entitled, **"The Effect of Renewal Processes Upon Stochastic Reliability Models."**
- Published graduate master's thesis and articles for United States Air Force flying training journals.
- Member: *Sigma Iota Epsilon* - National Honor Society in Management for outstanding graduate credit in Logistics Masters Degree program.
- Completed 8 technical training, qualification, and certification programs:
  - Undergraduate pilot training,
  - Combat crew training,
  - Combat crew special weapons certification,
  - Strategic Air Command Performance Officer Qualification,
  - Administrative Officer Qualification Training,
  - Directorate of Logistics Management course,
  - E-3 Aircraft Commander Qualification, and
  - E-3 Instructor Pilot Qualification Training.
- Completed Professional development courses
  - Squadron Officer School,
  - Air Command and Staff College, and
  - National Defense University.

ADDITIONAL INSTRUCTIONAL EXPERIENCE

- **University and college-level**

1995	Adjunct Professor, Business Division, Rose State College, Midwest City, OK
1994-96	Graduate Teaching Assistant, Department of Industrial Engineering, Oklahoma State University, Stillwater, OK
1988-90	Adjunct Professor of Management, College of Continuing Education, Hampton University, Hampton, VA

- **United States Air Force**

1981-85	Instructor Pilot, program assessment pilot
1973-75	Aircraft avionics lecturer

- **Gaylord Container Corporation**

1990-94	Instructor, *Technicomp®* (Quality Control Course)
1990-94	Instructor, United States Department of Transportation hazardous materials [HAZMAT Courses]
1990-94	Instructor, DuPont Corporation -- *Safety Training and Observation Program©*, [*S.T.O.P.*]

PROFESSIONAL ACTIVITIES

- Quality Examiner, *Oklahoma State Quality Award Foundation*, Department of Commerce, State of Oklahoma: 1996-1999
- Air Force Association, 1969-Present
- Wiley Post Flight, National Order of Daedalians, 1976-Present

ACADEMIC AFFILIATIONS

- Institute of Industrial Engineers, 1994-Present
- American Society for Engineering Education, 1997-Present
- American Society for Quality, 1990–Present
- Decision Sciences Institute, 2000–Present
- Production and Operations Management Society, 2000-Present
- Institute for Operations Research and the Management Sciences, 2000–Present
- Society of Logistics Engineers, 1975–Present
- World Association for Online Education (WAOE), 2001
- Multimedia Educational Resource for Learning and Online Teaching (MERLOT), 2001

HONORS

1976	*Sigma Iota Epsilon,* Honor Society of Operations Management
1995	*Alpha Pi Mu,* Honor Society of Industrial Engineering
2002	Nominated by the School of Industrial Engineering & Management, Oklahoma State University and selected by the Institute for Industrial Engineering (IIE) to attend inaugural Doctoral Colloquium, IIE National Conference, 18/19 May 02, Tampa, FL.

RESEARCH PROJECTS

Service

- Reviewer, Nineteenth Annual Southwest Business Symposium, University of Central Oklahoma.
- Reviewer, 2002 American Society for Engineering Education Annual Conference & Exposition, Manufacturing Division Track.

Presentations

- Quality Management: Abstract presented at the 19th Annual Business Symposium, University of Central Oklahoma, April 2002, **"Assessing the Effectiveness of Educational Portals to Create Value for Stakeholders."**
- Author of and presenter of paper, **"The Implementation of a Project-Based Quality Improvement Plan at 'XYZ' University: Improving Student Retention"**. Presented at the 16th Annual Business Symposium, University of Central Oklahoma, April 1999.
- Principal author and presenter of paper, **"The Motivation of the Technical Professional for Innovation in Production Operations"**. Presented at the 15th Annual Southwest Business Symposium, University of Central Oklahoma, April 1998.

Working

- Doctoral Dissertation: "*A Process To Model Customer-Focused Engineering Program Alignment By Means Of Group Consensus And Analytical Hierarchical Process Analysis*".
  - ➢ Doctoral Committee:
    - ⇨ Kenneth E. Case, Ph.D., Regents Professor and Director of the Engineering and Technology Management Graduate Program, School of industrial Engineering and Management, Chairman
    - ⇨ William J. Kolarik, PhD., Professor and Head of the School of industrial Engineering and Management
    - ⇨ Ramesh Sharda, Ph.D., Regents Professor of Management Science and Conoco / DuPont Chair of Technology Management, College of Business Administration.
    - ⇨ David B. Pratt, Ph.D., Associate Professor, School of industrial Engineering and Management
- David H. Hartmann and Manjunath Kamath, Ph.D. (Oklahoma State University). Collaborative Education: "*Determinants of a Quality Relationship in an INTERNET World*"
- David H. Hartmann and Paul Rossler, Ph.D. (Oklahoma State University). Quality Management: "*Parameters of Operationalizing Institutional Goals and Objectives*"
- Paul E. Rossler, Ph.D. (Oklahoma State University) and David H. Hartmann. "*Organizational Change: Why Some Sticks and Why Some Does Not*" (Working Title)

PROFESSIONAL DEVELOPMENT

- Completed additional graduate course work in management information systems: MIS 5113: Information Access Management, University of Oklahoma (OU) (fall semester, 2000). Course taken in residence at OU. Three credit hours received.
- Completed, spring semester 2001, IEM 5743: Information Systems and Technology, Oklahoma State University. Course taken via compressed video, University of Central Oklahoma.
- Student - Audited, "Using Active Server Pages to Develop Data-Driven Web Pages," NCEI, summer session 2000, University of Central Oklahoma.
- Student - Attended a three class series in WebCT training offered through the UCO Office of Information Technology and taught by Dr. Bill Morey, spring 2001.
- Student - Attended seminar, Oklahoma's first statewide Multimedia Educational Resource for Learning and Online Teaching (MERLOT), Friday, April 6, 2001.
- Attended, Southwest Business Symposium, April 19/20, 2001, University of Central Oklahoma.
- Attended the Annual Members Meeting of the World Association for OnLine Education, 29 June 2001.
- Student - Completed two-day seminar, "WebCT at UCO", fall 2001 Faculty Enhancement Day.
- Student - Attended seminar, "What's New at Chambers Library", fall 2001, Faculty Enhancement Day.
- Student - Attended seminar, "Violence in the Classroom", 27 Sep 01, CBA, Mr. J. Noftsger, presenter.
- Student - Attended eSeminar,"Developing OSSs: Benefits and Challenges," presented on-line by *The Net Economy*, 1:00-2:15 PM, 17 Oct 01.
- Approved to attend, "Grant Writing" seminar class to be instructed by the Center for Learning and Professional Development, University of Central Oklahoma.

Appendix 11 - Phase III Cover Letter: Academician Sample

David H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

[date]

[Name], Ph.D.
[address]
[address]

Dear Dr. [name]:

I am David Hartmann, a doctoral candidate at Oklahoma State University. I am conducting a study of engineering outcomes from manufacturing engineering programs. The intent of the study is to determine the characteristics of the engineering student holding the graduate degree, which manufacturers desire in their engineering employees to be competitive in their respective markets. In addition the research investigates the student's characteristics alignment between academic outcome and manufacturing requirements.

To pursue this research two paths of inquiry are ongoing -- academic and manufacturing. The manufacturing perceptions are complete. We now seek a consensus opinion of a select group of engineering academicians.

Your opinions, comments, and perceptions on the characteristics of the ideal engineering graduate student completing a curriculum towards an advanced degree will greatly contribute to the success of the study.

Request you identify an engineering educator generally conforming to the following specifications:

- The individual has earned the terminal Ph.D. in an engineering discipline;
- The panel member is a professional engineer as defined by the particular state's board of engineering registration in the state of their faculty assignment; and
- The panel member has been directly involved with the engineering department's business advisory committee or similar such committee.

The research project should not take any more than one hour to complete in three brief questionnaires during February 2003 – three hours total.

We have enclosed a stamped self-addressed post card on which you can indicate your preference to participate in the study.

The study has been designed in a way that you would not be asked any sensitive questions. The study will be conducted by an experienced researcher using a three step Delphi group process that will not ask for any information, which later could be traced to

Home: 405.359.3995 Email: Dhartm0669@aol.com
Office: 405.974.2839 Email: dhartmann@ucok.edu

any particular individual in the study. It is the "group's" opinion alone that will shape the outcome of the study. A survey will be sent to the member you nominate.

Respectfully, we request your reply by 1 February 2003.

If you have any questions regarding the study, please contact David H. Hartmann at (405) 974-2839 or e-mail at dhartmann@ucok.edu.

Thank you for your interest, assistance, and cooperation.

Sincerely,

David H. Hartmann
Researcher

Encl.: (1) Reply postcard

Home: 405.359.3995 Email: Dhartm0669@aol.com
Office: 405.974.2839 Email: dhartmann@ucok.edu

Oklahoma State University
322 EN
Stillwater, OK 74078

INFORMED CONSENT - Academician

A. AUTHORIZATION

I,_________________, hereby authorize or direct Mr. David H. Hartmann or associates or assistants of his choosing to perform the following treatment or procedure.

B. DESCRIPTION OF RESEARCH AND ASSOCIATED RISKS/BENEFITS

1. Research project is called: "A Process to Model Customer-Focused Engineering Program Alignment by Means of Group Consensus and Analytical Hierarchical Process Analysis".
2. This is exploratory research being conducted through Oklahoma State University by Mr. David Hartmann, Principal Investigator, doctoral student, School of Industrial Engineering and Management, OSU and Kenneth E. Case, Ph.D., doctoral advisor, School of Industrial Engineering and Management, OSU.
3. The purpose of the research is to obtain the written opinions of a group representing industrial engineering professors regarding the qualifications of engineering graduates. The research project will begin 28 April 2003 and conclude 31 July 2003.
4. Research participants will be asked to provide written responses in a commonly used research process known as the "Analytical Hierarchy Process Technique." The participants will receive a mailed survey seeking their ranking the importance of data collected from a cohort of the research external to the group. Participants will not be asked to place their names on any documentation. No academically proprietary information is required or solicited in this research. Mr. Hartmann will be present to hand out the surveys and to answer any questions. He will then depart the premises and the participants will independent of his direct influence to participate (or not) in the survey. A pre-stamped return envelope will be provided the participants.
5. None of the procedures used in the project are experimental.
6. There are no intentional physical risks or discomfort to the participants.
7. The research participants should not expect any direct benefits from the research.
8. In this research, there are no known alternative data collection methods, which could replace the written surveys.
9. Mr. Hartmann will keep all data collected from written surveys confidential and secured in a locked file cabinet in its original form or as computer data diskettes.
10. This research does not foresee any risk beyond minimal risk expected in daily life answering a questionnaire.
11. Whom to contact about the research: Mr. David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu, or postal address: D. H. Hartmann, 2801 Sweetbriar, Edmond, OK 73034.
12. Whom to contact about research subjects rights (the IRB office)
13. Additional contact: Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the principal investigator:

David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu,

Or postal address: D. H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

D. CONSENT DOCUMENTATION FOR WRITTEN INFORMED CONSENT

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________ Time: ____________________ (a.m. /p.m.)

____

Name (typed) Signature

____

Signature of person authorized to sign for subject, if required

Witness (es) if required: __________ Not / Required __________

__________ Not / Required __________

I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Signed: ____

Principal Investigator

Appendix 12 - Student Sample Informed Consent Letter

Oklahoma State University
322 EN
Stillwater, OK 74078

INFORMED CONSENT - Student

A. AUTHORIZATION

I,_________________, hereby authorize or direct Mr. David H. Hartmann or associates or assistants of his choosing, to perform the following treatment or procedure.

B. DESCRIPTION OF RESEARCH AND ASSOCIATED RISKS/BENEFITS

1. Research project is called: "A Process to Model Customer-Focused Engineering Program Alignment by Means of Group Consensus and Analytical Hierarchical Process Analysis".
2. This is exploratory research being conducted through Oklahoma State University by Mr. David Hartmann, Principal Investigator, doctoral student, School of Industrial Engineering and Management, OSU and Kenneth E. Case, Ph.D., doctoral advisor, School of Industrial Engineering and Management, OSU.
3. The purpose of the research is to obtain the written opinions of a group representing industrial engineering students regarding the qualifications of engineering graduates. The research project will begin 28 April 2003 and conclude 31 July 2003.
4. Research participants will be asked to meet [location to-be-determined] to provide written responses in a commonly used research process known as the "Analytical Hierarchy Process technique." The participants will receive a mailed survey seeking their ranking the importance of data collected from a cohort of the research external to the group. Participants will not be asked to place their names on any documentation, except for one sign in roster, which will be kept for the purpose of the correct spelling of participants and for mailing of the future survey. No commercially proprietary information is required or solicited in this research. Mr. Hartmann will be present to hand out the surveys and to answer any questions. He will then depart the premises and the students will independent of his direct influence to participate (or not) in the survey. A receptacle will be placed in such a position for the class to deposit their surveys, completed or not. A trusted student will be asked to volunteer to bring the box to Mr. Hartmann.
5. None of the procedures used in the project are experimental.
6. There are no intentional physical risks or discomfort to the participants.
7. The research participants should not expect any direct benefits from the research.
8. In this research, there are no known alternative data collection methods, which could replace the written surveys.
9. Mr. Hartmann will keep all data collected from written surveys confidential and secured in a locked file cabinet in its original form or as computer data diskettes.
10. This research does not foresee any risk beyond minimal risk expected in daily life answering a questionnaire.
11. Whom to contact about the research: Mr. David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu, or postal address: D. H. Hartmann, 2801 Sweetbriar, Edmond, OK 73034.
12. Whom to contact about research subjects rights (the IRB office)
13. Additional contact: Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone: 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the principal investigator:

David H. Hartmann, telephone: (405) 359-3995, Email: dhartmann@ucok.edu,

Or postal address: D. H. Hartmann
2801 Sweetbriar
Edmond OK 73034-6554

D. CONSENT DOCUMENTATION FOR WRITTEN INFORMED CONSENT

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ______________________ Time: ______________________ (a.m./p.m.)

____

Name (typed) Signature

____

Signature of person authorized to sign for subject, if required

Witness(es) if required: ____________ **Not / Required** ____________

____________ **Not / Required** ____________

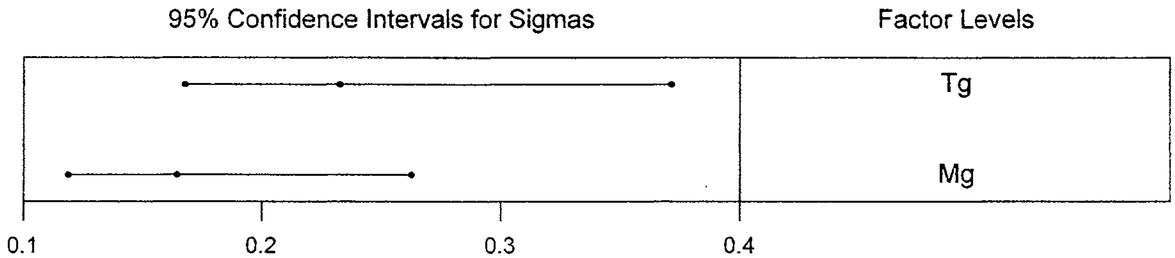
I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Signed: ____

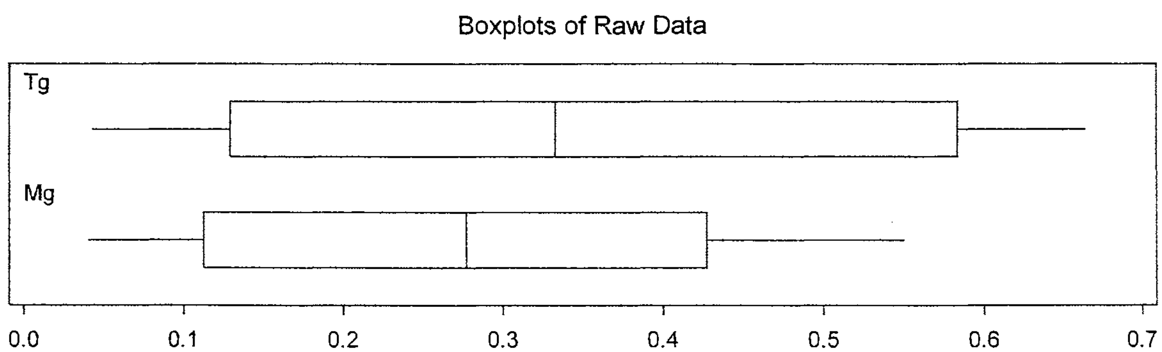
Principal Investigator

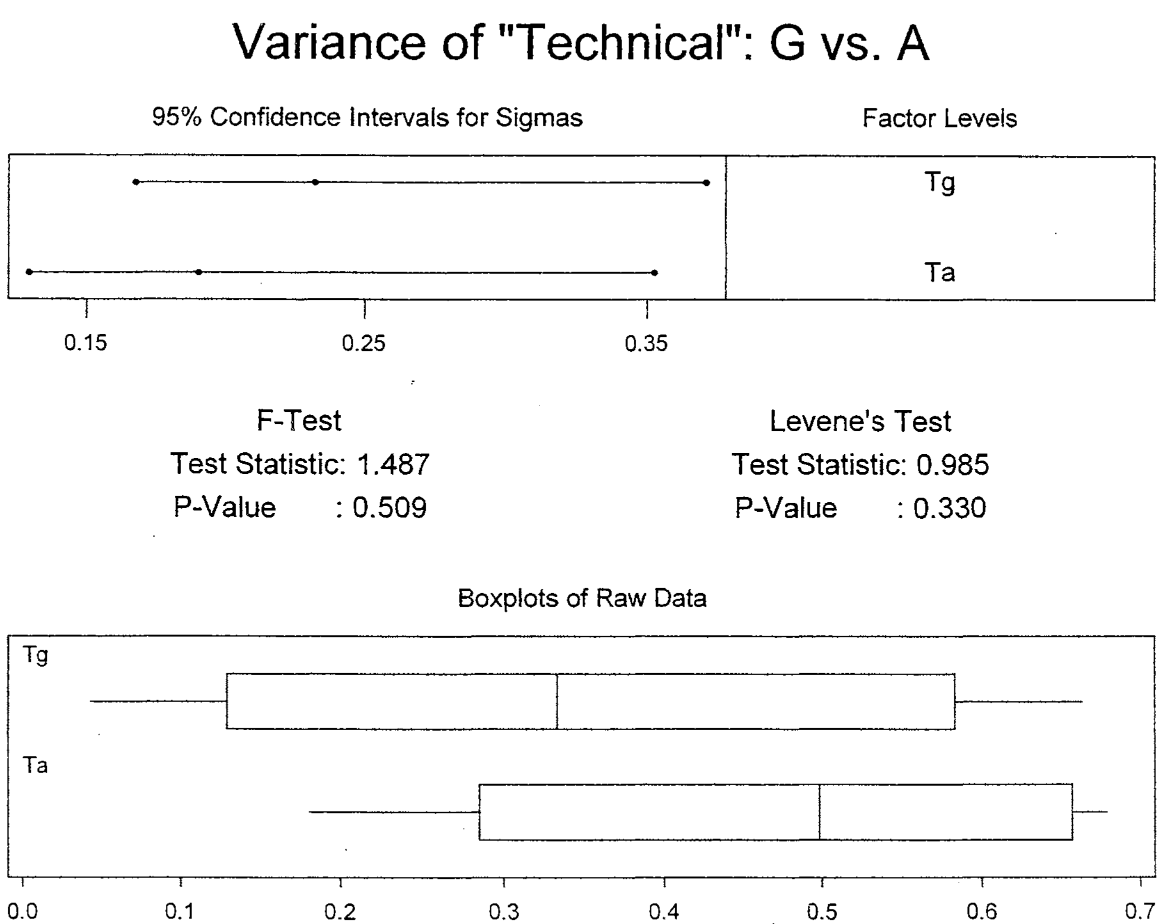
Appendix 13 - MINITAB©, Version 13.0 Analyses

Variance of "Technical": G vs. M

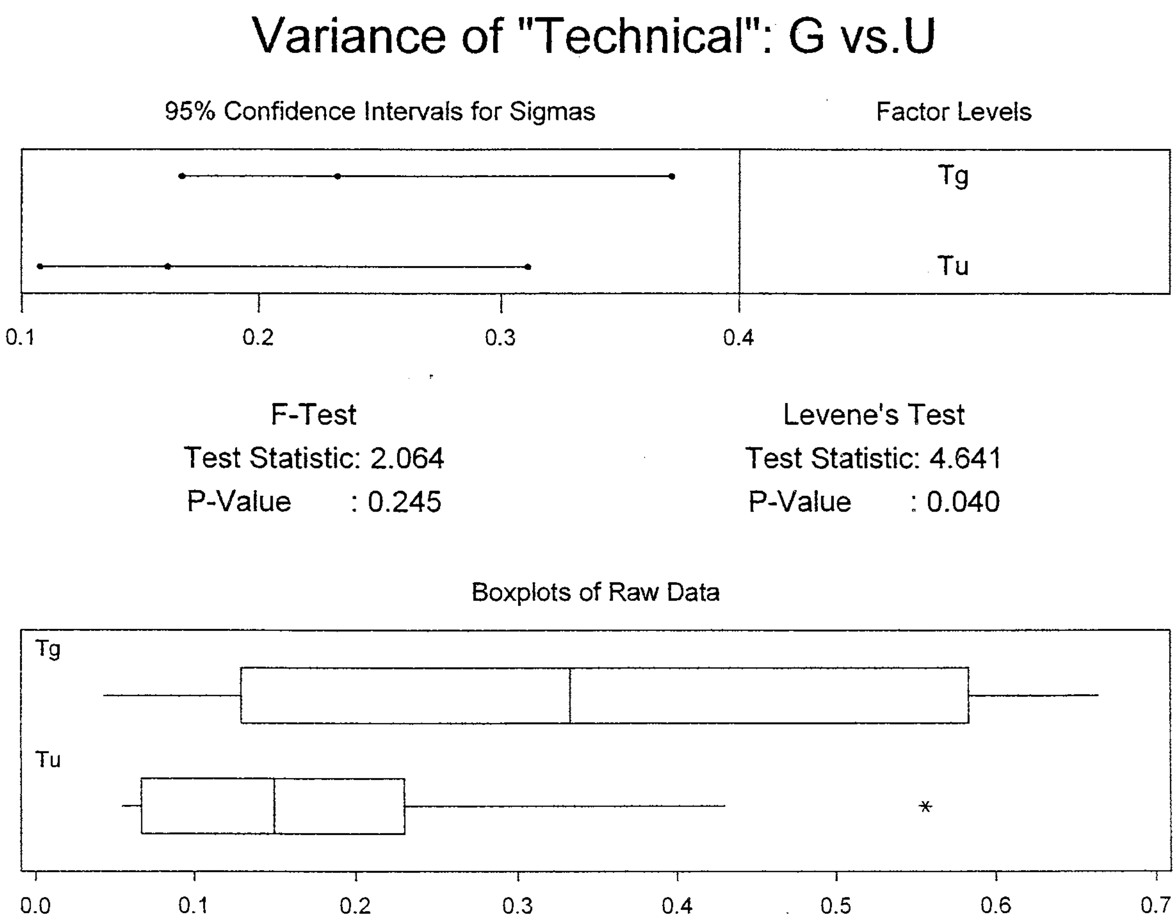


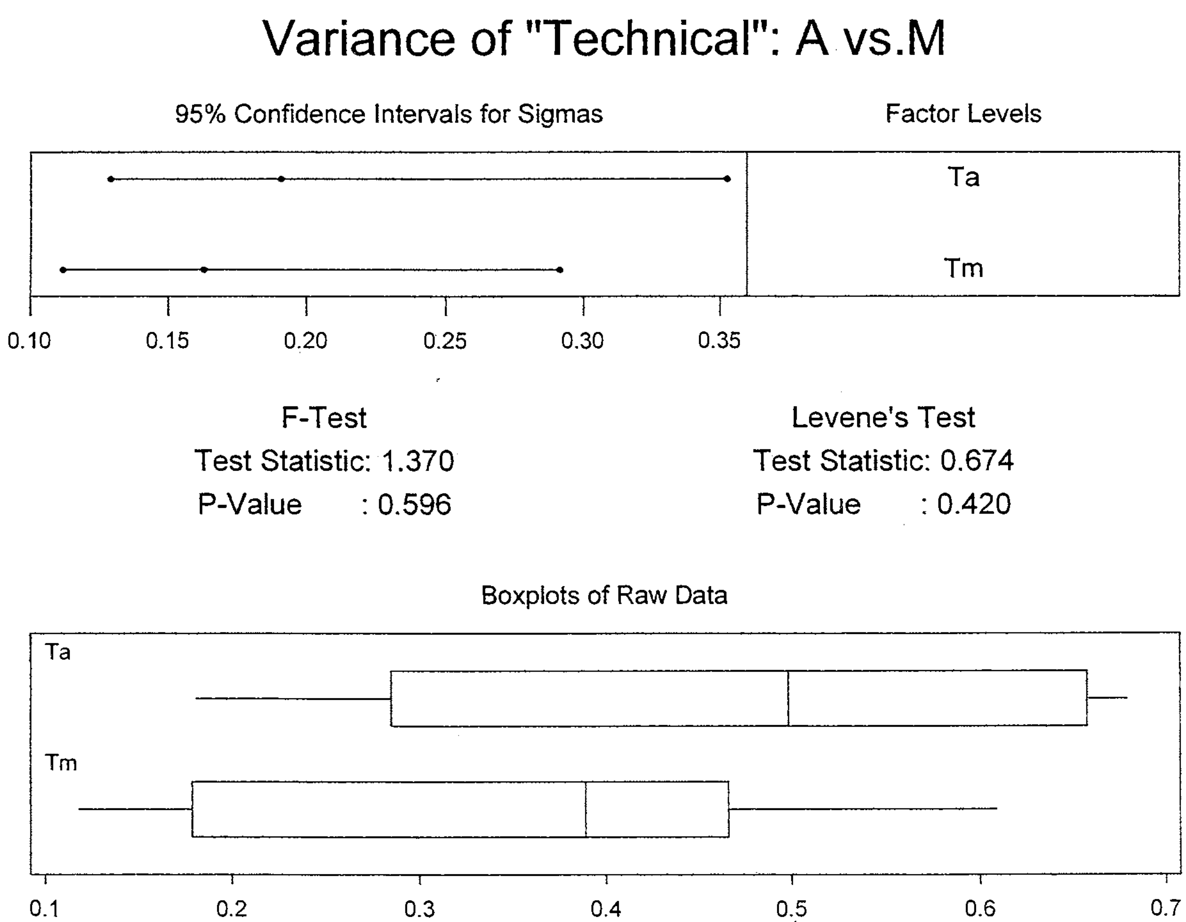
F-Test	Levene's Test
Test Statistic: 2.002	Test Statistic: 4.482
P-Value : 0.162	P-Value : 0.042

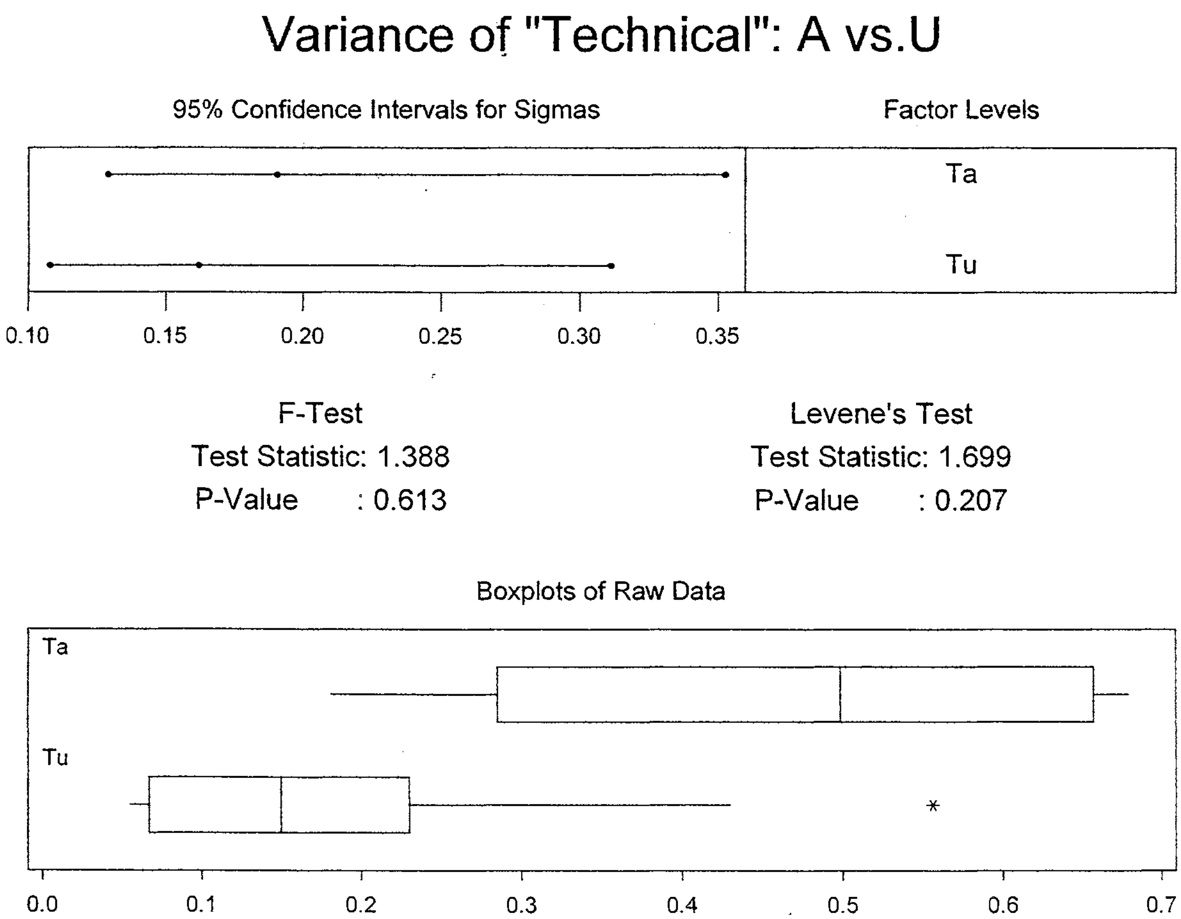




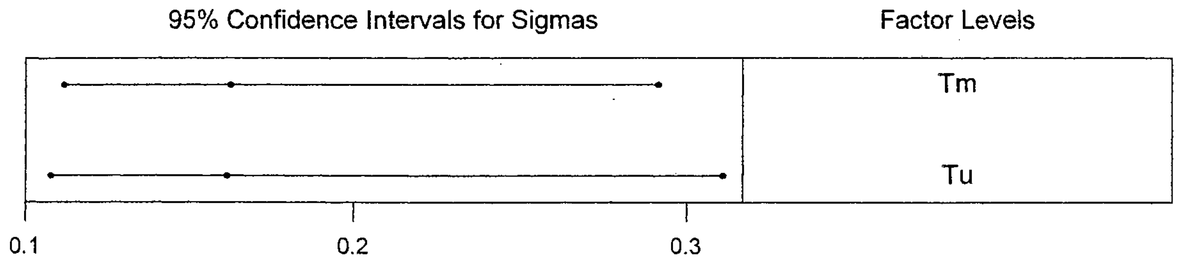
Variance of "Technical": G vs. A
95% Confidence Intervals for Sigmas
Factor Levels
Tg
Ta
0.15
0.25
0.35
F-Test
Test Statistic: 1.487
P-Value : 0.509
Levene's Test
Test Statistic: 0.985
P-Value : 0.330
Boxplots of Raw Data
Tg
Ta
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Variance of "Technical": G vs.U
95% Confidence Intervals for Sigmas
Factor Levels
Tg
Tu
0.1
0.2
0.3
0.4
F-Test
Test Statistic: 2.064
P-Value : 0.245
Levene's Test
Test Statistic: 4.641
P-Value : 0.040
Boxplots of Raw Data
Tg
Tu
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Variance of "Technical": A vs.M
95% Confidence Intervals for Sigmas
Factor Levels
Ta
Tm
0.10
0.15
0.20
0.25
0.30
0.35
F-Test
Test Statistic: 1.370
P-Value : 0.596
Levene's Test
Test Statistic: 0.674
P-Value : 0.420
Boxplots of Raw Data
Ta
Tm
0.1
0.2
0.3
0.4
0.5
0.6
0.7

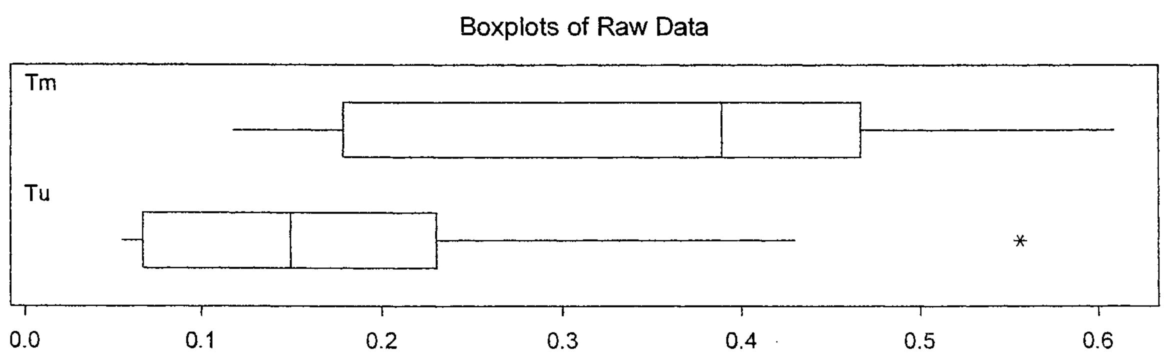

Variance of "Technical": A vs.U
95% Confidence Intervals for Sigmas
Factor Levels
Ta
Tu
0.10
0.15
0.20
0.25
0.30
0.35
F-Test
Test Statistic: 1.388
P-Value : 0.613
Levene's Test
Test Statistic: 1.699
P-Value : 0.207
Boxplots of Raw Data
Ta
Tu
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Variance of "Technical": M vs.U



F-Test
Test Statistic: 1.013
P-Value : 0.998

Levene's Test
Test Statistic: 0.387
P-Value : 0.540



Macro is running ... please wait

Test for Equal Variances

```
Level1     Tg
Level2     Tu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.167762	0.232473	0.371312	18	Tg
0.107744	0.161825	0.311018	11	Tu

F-Test (normal distribution)

```
Test Statistic: 2.064
P-Value       : 0.245
```

Levene's Test (any continuous distribution)

```
Test Statistic: 4.641
P-Value       : 0.040
```

Test for Equal Variances: Tg vs Tu

Macro is running ... please wait

Test for Equal Variances

```
Level1     Ta
Level2     Tm
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.128919	0.190647	0.352413	12	Ta
0.111671	0.162884	0.291279	13	Tm

F-Test (normal distribution)

```
Test Statistic: 1.370
P-Value       : 0.596
```

Levene's Test (any continuous distribution)

```
Test Statistic: 0.674
P-Value       : 0.420
```

Test for Equal Variances: Ta vs Tm

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Ta
Level2     Tu
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper      N  Factor Levels

0.128919  0.190647  0.352413    12   Ta
0.107744  0.161825  0.311018    11   Tu


F-Test (normal distribution)


Test Statistic: 1.388
P-Value       : 0.613


Levene's Test (any continuous distribution)


Test Statistic: 1.699
P-Value       : 0.207
```

Test for Equal Variances: Ta vs Tu

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Tm
Level2     Tu
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper      N  Factor Levels

0.111671  0.162884  0.291279    13   Tm
0.107744  0.161825  0.311018    11   Tu


F-Test (normal distribution)


Test Statistic: 1.013
P-Value       : 0.998


Levene's Test (any continuous distribution)


Test Statistic: 0.387
P-Value       : 0.540
```

Test for Equal Variances: Tm vs Tu

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Mg
Level2     Ma
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower     Sigma     Upper     N  Factor Levels

0.118552  0.164281  0.262394   18  Mg
0.046833  0.069258  0.128023   12  Ma


F-Test (normal distribution)


Test Statistic: 5.627
P-Value       : 0.006


Levene's Test (any continuous distribution)


Test Statistic: 7.368
P-Value       : 0.011
```

Test for Equal Variances: Mg vs Ma

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Mg
Level2     Mm
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower     Sigma     Upper     N  Factor Levels

0.118552  0.164281  0.262394   18  Mg
0.066023  0.096301  0.172212   13  Mm


F-Test (normal distribution)


Test Statistic: 2.910
P-Value       : 0.065


Levene's Test (any continuous distribution)


Test Statistic: 4.032
P-Value       : 0.054
```

Test for Equal Variances: Mg vs Mm

Macro is running ... please wait

Test for Equal Variances

```
Level1     Mg
Level2     Mu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.118552	0.164281	0.262394	18	Mg
0.093548	0.140503	0.270037	11	Mu

F-Test (normal distribution)

```
Test Statistic: 1.367
P-Value       : 0.626
```

Levene's Test (any continuous distribution)

```
Test Statistic: 0.737
P-Value       : 0.398
```

Test for Equal Variances: Mg vs Mu

Macro is running ... please wait

Test for Equal Variances

```
Level1     Ma
Level2     Mm
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
4.68E-02	6.93E-02	0.128023	12	Ma
6.60E-02	9.63E-02	0.172212	13	Mm

F-Test (normal distribution)

```
Test Statistic: 0.517
P-Value       : 0.285
```

Levene's Test (any continuous distribution)

```
Test Statistic: 0.619
P-Value       : 0.439
```

Test for Equal Variances: Ma vs Mm

Macro is running ... please wait

Test for Equal Variances

```
Level1     Ma
Level2     Mu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
4.68E-02	0.069258	0.128023	12	Ma
9.35E-02	0.140503	0.270037	11	Mu

F-Test (normal distribution)

```
Test Statistic: 0.243
P-Value       : 0.029
```

Levene's Test (any continuous distribution)

```
Test Statistic: 2.349
P-Value       : 0.140
```

Test for Equal Variances: Ma vs Mu

Macro is running ... please wait

Test for Equal Variances

```
Level1     Mm
Level2     Mu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
6.60E-02	0.096301	0.172212	13	Mm
9.35E-02	0.140503	0.270037	11	Mu

F-Test (normal distribution)

```
Test Statistic: 0.470
P-Value       : 0.216
```

Levene's Test (any continuous distribution)

```
Test Statistic: 0.782
P-Value       : 0.386
```

Test for Equal Variances: Mm vs Mu

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Sg
Level2     Sm
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper     N  Factor Levels

0.083095  0.115148  0.183917    18   Sg
0.111535  0.162686  0.290926    13   Sm


F-Test (normal distribution)


Test Statistic: 0.501
P-Value       : 0.188


Levene's Test (any continuous distribution)


Test Statistic: 1.883
P-Value       : 0.181
```

Test for Equal Variances: Sg vs Sm

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Sg
Level2     Sa
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper     N  Factor Levels

0.083095  0.115148  0.183917    18   Sg
0.108047  0.159782  0.295358    12   Sa


F-Test (normal distribution)


Test Statistic: 0.519
P-Value       : 0.218


Levene's Test (any continuous distribution)


Test Statistic: 1.817
P-Value       : 0.188
```

Test for Equal Variances: Sg vs Sa

Macro is running ... please wait

Test for Equal Variances

```
Level1     Sg
Level2     Su
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.083095	0.115148	0.183917	18	Sg
0.125750	0.188869	0.362994	11	Su

F-Test (normal distribution)

```
Test Statistic: 0.372
P-Value       : 0.070
```

Levene's Test (any continuous distribution)

```
Test Statistic: 5.183
P-Value       : 0.031
```

Test for Equal Variances: Sg vs Su

Macro is running ... please wait

Test for Equal Variances

```
Level1     Sa
Level2     Sm
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.108047	0.159782	0.295358	12	Sa
0.111535	0.162686	0.290926	13	Sm

F-Test (normal distribution)

```
Test Statistic: 0.965
P-Value       : 0.959
```

Levene's Test (any continuous distribution)

```
Test Statistic: 0.003
P-Value       : 0.953
```

Test for Equal Variances: Sa vs Sm

Macro is running ... please wait

Test for Equal Variances

Level1	Sa
Level2	Su
ConfLvl	95.0000

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.108047	0.159782	0.295358	12	Sa
0.125750	0.188869	0.362994	11	Su

F-Test (normal distribution)

Test Statistic: 0.716
P-Value : 0.590

Levene's Test (any continuous distribution)

Test Statistic: 0.749
P-Value : 0.396

Test for Equal Variances: Sa vs Su

Macro is running ... please wait

Test for Equal Variances

Level1	Sm
Level2	Su
ConfLvl	95.0000

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.111535	0.162686	0.290926	13	Sm
0.125750	0.188869	0.362994	11	Su

F-Test (normal distribution)

Test Statistic: 0.742
P-Value : 0.616

Levene's Test (any continuous distribution)

Test Statistic: 0.609
P-Value : 0.443

Test for Equal Variances: Sm vs Su

Macro is running ... please wait

Test for Equal Variances

Level1	Pg
Level2	Pm
ConfLvl	95.0000

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.124477	0.172492	0.275509	18	Pg
0.040618	0.059246	0.105947	13	Pm

F-Test (normal distribution)

Test Statistic: 8.477
P-Value : 0.001

Levene's Test (any continuous distribution)

Test Statistic: 3.105
P-Value : 0.089

Test for Equal Variances: Pg vs Pm

Macro is running ... please wait

Test for Equal Variances

Level1	Pg
Level2	Pa
ConfLvl	95.0000

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.124477	0.172492	0.275509	18	Pg
0.064466	0.095333	0.176223	12	Pa

F-Test (normal distribution)

Test Statistic: 3.274
P-Value : 0.050

Levene's Test (any continuous distribution)

Test Statistic: 1.245
P-Value : 0.274

Test for Equal Variances: Pg vs Pa

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Pg
Level2     Pu
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper      N  Factor Levels

0.124477  0.172492  0.275509    18  Pg
0.156493  0.235044  0.451739    11  Pu


F-Test (normal distribution)


Test Statistic: 0.539
P-Value       : 0.251


Levene's Test (any continuous distribution)


Test Statistic: 0.913
P-Value       : 0.348
```

Test for Equal Variances: Pg vs Pu

```
Macro is running ... please wait
```

Test for Equal Variances

```
Level1     Pa
Level2     Pm
ConfLvl    95.0000

Bonferroni confidence intervals for standard deviations

  Lower      Sigma      Upper      N  Factor Levels

6.45E-02  9.53E-02  0.176223    12  Pa
4.06E-02  5.92E-02  0.105947    13  Pm


F-Test (normal distribution)


Test Statistic: 2.589
P-Value       : 0.117


Levene's Test (any continuous distribution)


Test Statistic: 0.686
P-Value       : 0.416
```

Test for Equal Variances: Pa vs Pm

Macro is running ... please wait

Test for Equal Variances

```
Level1     Pa
Level2     Pu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.064466	0.095333	0.176223	12	Pa
0.156493	0.235044	0.451739	11	Pu

F-Test (normal distribution)

```
Test Statistic: 0.165
P-Value       : 0.006
```

Levene's Test (any continuous distribution)

```
Test Statistic: 3.743
P-Value       : 0.067
```

Test for Equal Variances: Pa vs Pu

Macro is running ... please wait

Test for Equal Variances

```
Level1     Pm
Level2     Pu
ConfLvl    95.0000
```

Bonferroni confidence intervals for standard deviations

Lower	Sigma	Upper	N	Factor Levels
0.040618	0.059246	0.105947	13	Pm
0.156493	0.235044	0.451739	11	Pu

F-Test (normal distribution)

```
Test Statistic: 0.064
P-Value       : 0.000
```

Levene's Test (any continuous distribution)

```
Test Statistic: 6.680
P-Value       : 0.017
```

Test for Equal Variances: Pm vs Pu

```
Saving file as: C:\Program Files\MTBDEMO\Data\PHD_GAMU_Group_EqVarAnalysis.MTW
* NOTE  * Existing file replaced.
```

Distribution Function Analysis

Normal Dist. Parameter Estimates (ML)

Variable: Tg

Mean 0.338167
StDev 0.225923

Goodness of Fit

Anderson-Darling (adjusted) = 1.233

Percentile Estimates

Percent	Percentile	95% CI Approximate Lower Limit	95% CI Approximate Upper Limit
1	-1.9E-01	-3.9E-01	0.01351
2	-1.3E-01	-3.1E-01	0.05820
3	-8.7E-02	-2.6E-01	0.08692
4	-5.7E-02	-2.2E-01	0.10874
5	-3.3E-02	-1.9E-01	0.12665
6	-1.3E-02	-1.7E-01	0.14202
7	0.004752	-1.5E-01	0.15560
8	0.020729	-1.3E-01	0.16785
9	0.035259	-1.1E-01	0.17908
10	0.048635	-9.2E-02	0.18948
20	0.148025	0.026572	0.26948
30	0.219693	0.108379	0.33101
40	0.280930	0.174899	0.38696
50	0.338167	0.233798	0.44254
60	0.395404	0.289373	0.50143
70	0.456641	0.345327	0.56795
80	0.528308	0.406855	0.64976
90	0.627698	0.486851	0.76855
91	0.641074	0.497256	0.78489
92	0.655604	0.508481	0.80273
93	0.671582	0.520734	0.82243
94	0.689426	0.534317	0.84453
95	0.709777	0.549688	0.86987
96	0.733687	0.567597	0.89978
97	0.763081	0.589417	0.93674
98	0.802155	0.618130	0.98618
99	0.863742	0.662823	1.06466

Prob Plot for Tg

Distribution Function Analysis

Normal Dist. Parameter Estimates (ML)

Variable: Ta

Mean 0.475
StDev 0.182531

Goodness of Fit

Anderson-Darling (adjusted) = 1.493

Percentile Estimates

Percent	Percentile	95% CI Approximate Lower Limit	95% CI Approximate Upper Limit
1	0.050370	-1.5E-01	0.24918
2	0.100128	-8.2E-02	0.28222
3	0.131697	-4.0E-02	0.30354
4	0.155446	-8.9E-03	0.31979
5	0.174764	0.016353	0.33317
6	0.191206	0.037724	0.34469
7	0.205623	0.056357	0.35489
8	0.218531	0.072950	0.36411
9	0.230271	0.087961	0.37258
10	0.241077	0.101707	0.38045
20	0.321378	0.201199	0.44156
30	0.379281	0.269135	0.48943
40	0.428756	0.323838	0.53368
50	0.475000	0.371725	0.57827
60	0.521244	0.416325	0.62616
70	0.570719	0.460573	0.68087
80	0.628622	0.508443	0.74880
90	0.708923	0.569552	0.84829
91	0.719729	0.577419	0.86204
92	0.731469	0.585888	0.87705
93	0.744377	0.595111	0.89364
94	0.758794	0.605312	0.91228
95	0.775236	0.616826	0.93365
96	0.794554	0.630206	0.95890
97	0.818303	0.646460	0.99015
98	0.849872	0.667777	1.03197
99	0.899630	0.700818	1.09844

Prob Plot for Ta

Macro is running ... please wait

Dotplot for Tg-Tu

Macro is running ... please wait

Dotplot for Mg-Mu

Macro is running ... please wait

Dotplot for Sg-Pu

Macro is running ... please wait

Dotplot for Tg-Pu

Dotplot for Tg-Pu

```
Macro is running ... please wait
```

Dotplot for Sg-Pu

```
Macro is running ... please wait
```

Dotplot for Tg-Mu

Appendix 14 - Phase III Academician Status Record

360

✓ EMail (5/6/03) Copying INFORMED CONSENT

State	School	Individual Contacted	Remarks:	PHONE
Arkansas	University of Arkansas ✓	JRE@ENGR.UARK.EDU John R. English, Ph.D., P.E.	USPS EXPRESS 4/28 (5/9) G-5/12	
Oklahoma	Oklahoma State University ✓	CHARLENE A. YAUCH, Ph.D., P.E.	HANDCARRIED 5/6/03 (5/16) G-5/9	m/r
		Paul E. Rossler, Ph.D., P.E.	USPS PRIORITY 4/24 (5/9) G-5/7	m/r
	University of Oklahoma ✓	Thomas L. Landers, Ph.D., P.E. TERRY REED RHOADS, Ph.D.	HANDCARRIED 5/7/03 (5/14) Got 5/18	mR m/R
Kansas	Kansas State University ✓	Bradley A. Kramer, Ph.D. ✓✓	USPS EXPRESS 4/30 (5/16): Got 5/18	
	University of Kansas ✓	Robert P. Zewrwekh, Ph.D. ✓✓	USPS EXPRESS 4/30 (5/16): Phone Got 5/18	m/r
	Wichita State University ✓	Abu S. M. Masud, Ph.D. ✓✓	Got 5/3/03 complete	
Louisiana	Louisiana State University ✓	Thomas G. Ray, Ph.D. ✓✓	USPS EX 4/30 (5/16) Got but	[illegible]
	Louisiana Technical University ✓	Jun-Ing Ker, Ph.D. ✓✓	USPS EX 4/30 (5/16) Got 5/18	
Missouri	University of Missouri ✓	Cerry M. Klein, Ph.D. ✓✓	USPS EX 4/30 (5/16) G-5/9	
	University of Missouri-Rolla ✓	Cihan H. Dagli, Ph.D. ✓✓	USPS EX 4/30 (5/16)	
New Mexico	New Mexico State University ✓	Edward Pines, Ph.D. ✓✓	USPS EX 4/30 (5/16): REC'd EMAIL w/ APPROVAL G-5/9	
Texas	Lamar University	Victor A. Zaloom, Ph.D., P.E. alternative. James L. Thomas, Ph.D.		
	Texas A.& M. - Commerce	Jerry D. Parish, Ed.D.		
	Texas A.& M. - Coll. Stn. ✓	Brett A. Peters, Ph.D. ✓✓	USPS EX 4/30 (5/16) G-5/12	
	Texas Technical University	~~Milton L. Smith, Ph.D., P.E.~~ (BERQUVIST ✓✓	USPS EX 4/30 (5/16) G-5/7	m/r
	University of Houston ✓	Hamid R. Parsaei, Ph.D., P.E. ✓✓	USPS EX 4/30 (5/16)	
	University of Texas-Arlington ✓	Donald H. Liles, Ph.D. — ✓✓	USPS EX 4/30 (5/16)	
	University of Texas-El Paso	Louis Everett, Ph.D.		

"ENGINEERING MANAGEMENT,"
"INDUSTRIAL" OR "MANUFACTURING ENGINEERING"

OKLAHOMA STATE UNIVERSITY	ROSSLER (P) 4/24 ✓ (E) 4/23 ✓ mailed
UNIV. OF OKLAHOMA	LANDERS
~~OKLAHOMA CHRISTIAN UNIVERSITY~~ LAMAR UNIVERSITY	ZALOOM
TULSA UNIVERSITY	[ ] [illegible] F. Rossler
KANSAS STATE UNIVERSITY	KRAMER
UNIV. OF TEXAS — ARLINGTON	LILES
UNIV. OF ARKANSAS	ENGLISH Letter [illegible] 4/24/03 mailed 4/28/03 Expires w/ [illegible]
UNIV. OF MISSOURI — ROLLA	DAGLI
UNIV. OF HOUSTON	PARSAEI

Texas:

Texas A&M-Commerce

Dr. Jerry D. Parish, CSIT
Professor & Department Head
Department of Industrial Engineering & Technology College of Business & Technology
P.O. Box 3011
Commerce, TX 75429-3011
Telephone: 903-886-5474
E-Mail: Jerry_Parish@tamu-commerce.edu

Department of Industrial Engineering, Texas A&M, College Station

Dr. Brett Peters
Interim Department Head
241 Zachry Engineering Research Center
979-845-5531
bpeters@tamu.edu

237 A Zachry Engineering Center
3131 TAMUS
College Station, TX 77843-3131

Texas Tech University, Lubbock

Dr. Milton L. Smith
Department of Industrial Engineering
Texas Tech University
Box 43061
Lubbock, TX 79409-3061
(806) 742-3543
milton.smith@coe.ttu.edu

Dr. Mario G. Beruvides
Texas Tech University (M.S. in Systems and Engineering management)
Industrial Engineering Department
P.O. Box 43061
Lubbock, Texas 79409-3061
Phone: 806-742-3543
Fax: 806-742-3411

University of Texas at Arlington

Prof. Don Lilies
Department of Industrial & Manufacturing Systems Engineering
PO Box 19017
The University of Texas at Arlington
Arlington TX 76019
817-272-3160
dliles@uta.edu

701 S. Nedderman drive

University of Texas, Austin
Operations Research and Industrial Engineering Program

Jonathan F. Bard
Coordinator
Department of Mechanical Engineering
ETC 5.160, C2200
The University of Texas
Austin, TX 78712-1063
512-471-3076 (office)
512-232-1489 (fax)
jbard@mail.utexas.edu

The University of Texas at El Paso

Mechanical and Industrial Engineering Department
Dr. Louis Everett
Phone: (915) 747-7987
Fax: (915) 747-5019
leverett@utep.edu

500 West University Ave
El Paso, Texas 79968.

Kansas

Kansas State University
Department of Industrial and Manufacturing Systems Engineering
Bradley A. Kramer
Associate Professor and Head
785-532-5606
bradleyk@ksu.edu

237, Durland hall
Manhattan, KS-66506-5101
USA

Wichita State University
ABU. S. M. MASUD
Professor and Chair
abu.masud@wichita.edu
100 Wallace Hall
1845 N. Fairmount
Wichita, KS 67260-0044
(316) 978-5900
(316) 978-3742 - fax

Engineering Management
KU Edwards Campus
12600 Quivira Road, Room 225
Overland Park, KS 66213
Phone: (913) 897-8560
Fax: (913) 897-8682
E-mail: emgt@ku.edu

Zerwekh Robert. P. Director of EMGT Program

913-897-8561

bzerwekh@ku.edu

Missouri

University of Missouri – Columbia
Industrial and Manufacturing Systems Engineering

Cerry Klein
Chair and Professor
E3437 Engineering Building East
573-882-2691

E 34371 Engr Bldg. East
University of [illegible]
Columbia, MO 65211

Louisiana

Industrial and Manufacturing Systems Engineering
3128 CEBA, Louisiana State University
Baton Rouge, LA 70803
Phone: (225) 578-5112; Fax: (225) 578-5109

THOMAS G. RAY, Ph.D.
Associate Professor
Chair (IMSE Program)
Louisiana State University
Phone: (225) 578-5369; E-mail: trav@lsu.edu

Louisiana Tech University

Dr. Jun-Ing Ker,
Industrial Engineering Program Chair
318-257-2963,
ker@engr.latech.edu

204 Bogard Hall
Ruston, LA, 71272

Industrial Engineering Program
Louisiana Tech University
P.O. Box 10348
Ruston, LA 71272

New Mexico

New Mexico State University
P.O.BOX 30001 MSC 4230,
Las Crusus
NM 88003-8001

Edward Pines
Associate Professor and
Academic Department Head
epines@nmsu.edu
505-646-2730

Department of Industrial Engineering
201 Engineering Complex III
Las Cruces, NM 88011

Oklahoma State University Mailed 4/25/03

Dr. Paul E Rossler,
(Director, MS in Engineering and Technology Management Program)
Room 329A North Hall
700 North Greenwood Ave
Tulsa, OK 74106
918-594-8289 Main Office
918-594-8281 Fax

Brenda L. Johnson (Assistant Director)
106 Engineering North
Stillwater OK 74078
405-744-2337 Main office
405-744-9219 Direct line/Voice Mail
405-744-1673FAX
brendaj@okstate.edu

University of Oklahoma

Dr. Pakize S.Pulat (Director)
School of Industrial Engineering
University of Oklahoma
202 West Boyd, Room 124
Norman, OK 73019-0631
Phone 405-325-3721
Fax 405-325-7555
pulat@ou.edu

University of Tulsa

Master of Engineering and Technology Management
Tel: 918.631.2242
Fax: 918.631.2142
graduate-business@utulsa.edu

Kansas State University

Industrial and Manufacturing Systems Engineering
Dr. Bradley A Kramer (Associate Professor and Head)
Tel: 785-532-5606
bradleyk@ksu.edu

University of Texas at Arlington

Department of Industrial & Manufacturing systems Engineering
Donald H. Liles (Chair)
Tel: 817-272-3160
dliles@uta.edu

University of Arkansas

Department of Industrial Engineering
4207 Bell Engineering Center
University of Arkansas
Fayetteville, AR 72701
Tel: 479-575-3156
Fax: 479-575-8413

Dr. John R. English (Department Head)
Bell Engineering Center, Rm.4212
Tel: 479-575-6029
jre@engr.uark.edu

University of Missori – Rolla

Department of Engineering Management

Dr. Cihan H. Dagli (Interim Department Chair)
RM229 Engineering Management
1870 Miner Circle
Rolla, MO 65409-0370
Tel: 573-341-4374
Fax: 573-341-6567
dagli@umr.edu

University of Houston

HAMID R. PARSAEI, Ph.D., P.E.
Professor and Chairman
Ph.D. The University of Texas at Arlington

4800 Calhoun Street
Houston, TX 77204
(713) 743-6041
E-mail: parsaei@uh.edu

Lamar University

Dr. Victor Zaloom, P.E.

Phone:	(409) 880-8804
Fax:	(409) 880-8121
Email:	zaloomva@hal.lamar.edu
Web:	http://dept.lamar.edu/industrial/index.html

2

VITA

David Herbert Hartmann

Candidate for the Degree of

Doctor of Philosophy

Thesis: MODELING CUSTOMER-FOCUSED ENGINEERING PROGRAM ALIGNMENT BY MEANS OF GROUP CONSENSUS AND ANALYTICAL HIERARCHY PROCESS ANALYSIS

Major Field: Industrial Engineering

Biographical:

Education: Earned the Bachelor of Science degree, 1969, United States Air Force Academy, Colorado Springs, CO. Earned the Master of Science degree in Logistics Management, 1976, Air Force Institute of Technology, Wright-Patterson Air Force Base, Dayton, OH. Earned the Master of Business Administration degree, 1987, College of William and Mary in Virginia, Williamsburg, VA. Completed the requirements for the Doctor of Philosophy degree with a major in Industrial Engineering in May, 2004.

University of Central Oklahoma, Edmond, OK 2000-Present
Instructor, Department of Information Systems and Operations Management

- Teaching Experience:
  - Production and Operations Management (Undergraduate),
  - Methods of Operations Supervision (Undergraduate),
  - Management Science (Undergraduate and Graduate), and
  - Management Information Systems (Undergraduate).
- Serves on a variety of Departmental academic committees:
  - Department Liaison to the Max Chambers Library, 2001-Present
  - Honors and Scholarship Committee, 2000-2001
  - Department Program Review Committee, 2000-2001
  - Liaison to Rose State College – Operations Management, 2001-Present
- Served on the University's Presidential Leadership Council Scholarship Screening Committee, 2000-2001

Saint Gregory's University, Shawnee, OK 1996-2000
<u>Chair, Division of Business and Decision Sciences</u>

- Set Division policy, developed the business core academic curriculum, and developed, tracked, and reported variances in annual division budgets.
- Sourced, screened, interviewed, and recommended full-time and adjunct faculty.
- Instructed fifteen (15) equated credit hours of quantitative and qualitative upper division courses per academic semester.
- Recruited, enrolled, and advised students.
- Developed a unique, integrative fourteen credit hour program in **Professional Development** required of all university students.
- Teaching Experience: (all undergraduate)
  - ➢ Production and Operations Management,
  - ➢ Principles of Management,
  - ➢ Total Quality Management,
  - ➢ Organizational Policies and Practices (Interdisciplinary general education course),
  - ➢ Principles of Business Communication,
  - ➢ International Management, and
  - ➢ Senior Seminar: Business Research and Strategy.
- Co-Chair, University <u>Academic Council</u>.
- Served on a variety of academic committees:
  - ➢ Co-chair of the <u>Technology Integration Project Team</u>, which developed and implemented the campus-wide adoption of laptop computers by students, faculty, and staff.
  - ➢ Served on the <u>Distance Learning Implementation Team,</u>
  - ➢ Served on the <u>Library Resources Committee,</u>
  - ➢ Served on the University <u>Self-Assessment Committee</u>, and
  - ➢ Served on the University <u>Adults Completing Education (A.C.E.) Committee</u>.

Oklahoma State University, Stillwater, OK 1994-Present
<u>Doctoral Candidate and Graduate Research Assistant</u>

- Completed all course work towards the Ph.D. in Industrial Engineering and Management. GPA: 3.35/4.00. Elected to *Alpha Pi Mu* -- National Industrial Engineering Honor Society. Graduate Teaching Assistant, 1994-96.
- Served as research assistant in an OSU and federal government cooperative Computer Assisted Technology Transfer Program (CATT) grant whose goal is the transfer of manufacturing technologies and training to Oklahoma manufacturers.

Gaylord Container Corporation, Rochester, NY 1990-94
Quality Process Manager

- Chaired the manufacturing plant quality council and facilitated 25 quality improvement teams.
- Implemented procedures and monitored statistical data to assure assessment standards were achieved in areas of personnel training, product manufacturing, and supplier selection.
- Initiated and developed procedures for supplier certification in accordance with ISO-9000 standards series. Documented success led to corporate-wide adoption in selected manufacturing operations and supplier certification.
- Initiated and hired engineering student interns for plant-wide quality improvement.
- Served on the facility's various social and community service committees.

United States Air Force 1969-90
Retired Rank: Lieutenant Colonel

SUMMARY OF EXPERIENCE IN MILITARY SETTING

During term of commissioned service, rapidly progressed through positions of increasing leadership and management responsibility including instructor pilot, standards and evaluation pilot, operations officer, squadron commander, and program and project manager.

Summary of career experience includes:

10 years	Designed and managed programs for evaluating and financially controlling flying training and technical education courses in the United States Air Force and in twenty-two (22) foreign air forces.
10 years	Developed and managed annual operating budgets in excess of $500,000.
6 years	Managed forty-five (45) flight training program evaluations and continuing education needs assessments.
5 years	Designed and implemented assessment programs for ten (10) aviation-training organizations.
5 years	Initiated and implemented improved logistics assessment designs for organizations in the United States Air Force and three (3) foreign air forces on behalf of the Department of State of the United States of America.

Military career highlights

- Instructor pilot and flight examiner: E-3A, B, C AWACS and EC/KC-135A aircraft.
- Veteran: Vietnam War and Persian Gulf Conflict and numerous contingency air campaigns of national significance.

Hampton University, Hampton, VA

Undergraduate course taught: *"Principles of Management"*

- **United States Air Force**

1981-85 Instructor Pilot, program assessment pilot

1973-75 Aircraft avionics lecturer

- **Gaylord Container Corporation**

1990-94 Instructor, *Technicomp®* (Quality Control Course)

1990-94 Instructor, United States Department of Transportation hazardous materials [HAZMAT Courses]

1990-94 Instructor, DuPont Corporation -- *Safety Training and Observation Program©*, [*S.T.O.P.*]

PROFESSIONAL ACTIVITIES

- Quality Examiner, *Oklahoma State Quality Award Foundation*, Department of Commerce, State of Oklahoma: 1996-1999
- Air Force Association, 1969-Present
- Wiley Post Flight, National Order of Daedalians, 1976-Present

ACADEMIC AFFILIATIONS

- Institute of Industrial Engineers, 1994-Present
- American Society for Engineering Education, 1997-Present
- American Society for Quality, 1990–Present
- Decision Sciences Institute, 2000–Present
- Production and Operations Management Society, 2000-Present
- Institute for Operations Research and the Management Sciences, 2000–Present
- Society of Logistics Engineers, 1975–Present
- World Association for Online Education (WAOE), 2001
- Multimedia Educational Resource for Learning and Online Teaching (MERLOT), 2001

HONORS

1976	*Sigma Iota Epsilon,* Honor Society of Operations Management
1995	*Alpha Pi Mu,* Honor Society of Industrial Engineering
2002	Nominated by the School of Industrial Engineering & Management, Oklahoma State University and selected by the Institute for Industrial Engineering (IIE) to attend inaugural Doctoral Colloquium, IIE National Conference, 18/19 May 02, Tampa, FL.

ACADEMIC SERVICE

- Elected Member, University of central Oklahoma Academic Affairs Council, 2003 – Present
- Member, College of Business Administration Undergraduate Curriculum Committee, 2003 – Present

Service

- Reviewer, Nineteenth Annual Southwest Business Symposium, University of Central Oklahoma.
- Reviewer, 2002 American Society for Engineering Education Annual Conference & Exposition, Manufacturing Division Track.

Presentations

- Quality Management: Abstract presented at the 19th Annual Business Symposium, University of Central Oklahoma, April 2002, **"Assessing the Effectiveness of Educational Portals to Create Value for Stakeholders."**
- Author of and presenter of paper, **"The Implementation of a Project-Based Quality Improvement Plan at 'XYZ' University: Improving Student Retention".** Presented at the 16th Annual Business Symposium, University of Central Oklahoma, April 1999.
- Principal author and presenter of paper, **"The Motivation of the Technical Professional for Innovation in Production Operations".** Presented at the 15th Annual Southwest Business Symposium, University of Central Oklahoma, April 1998.